Assessment of Short Span Bridge Materials

by

John R. Brown

A research paper submitted in partial fulfillment
of the requirements for the degree of

Master of Science in Engineering

University of Washington

1990

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Abstract

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Chairperson of the Supervisory Committee: Associate Professor
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There are approximately 1877 substandard bridges on the federal aid system and 2193 substandard bridges off the federal aid system in Idaho, Oregon, and Washington (Secretary of Transportation,1989).

In general a bridge can be divided into the substructure, superstructure, and decking. The choice of construction materials is critical for the function and economics of all elements. Wood, steel, and concrete are the principle materials utilized.

Each of these materials has characteristics that add and detract from use in short span bridges. A review of current literature provided insight into what factors were considered important. A survey of how counties have replaced deficient structures in the past provides information on materials that will be in demand in the future.

This research focused on the criteria that county engineers in Idaho, Oregon, and Washington consider when selecting material for a short span bridge structure.

A survey was prepared and forwarded to county officials in Idaho, Oregon, and Washington to determine past practices and anticipated future trends. A response from 42% of the counties provided valuable insight into short span bridges in the Northwest.

One of the most significant facts is that precast concrete structures are predominately utilized for the superstructure and decking. There are a number of counties that have special considerations that allow for the use of wood and steel structures but they are the exception. The preponderance of county officials recognize precast elements as the most superior material both in performance and economics.

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ACKNOWLEDGMENTS

The author wishes to extend a sincere thank you to Professor Jimmie Hinze for his assistance in the preparation of this research paper.

DEDICATION

A special note of appreciation goes to my wife, whose support and encouragement throughout this project enabled me to see the light. This research paper is dedicated to her.

Introduction

Because of the publicity generated by bridge failures and the deteriorating condition of the nation's bridges, Congress passed the 1968 Federal Highway Act. This statute mandated that all bridges on the federal-aid system receive a biannual inspection and that the Federal Highway Administration maintain records of these inspections. With passage of the Surface Transportation Assistance Act (SAA) of 1978, the biannual inspection requirements for bridges were expanded to include all bridges not on the federal aid system (TRB Special Report 202, 1984). In 1987 the Surface Transportation and Uniform Relocation Assistance Act (STURAA) extended the Highway Bridge Replacement and Rehabilitation Program (HBRRP) to low water crossings (Secretary of Transportation, 1989). As of June 1988 there were 98,526 structurally deficient bridges and 62,639 functionally obsolete bridges off the Federal-aid system (Secretary of Transportation, 1989).

Short span bridges are not as visible to the public as the highway bridges on the Federally funded road system. However these bridges on the secondary roads play a vital role in this country's overall transportation system. The number that require repair or replacement represents a significant expenditure of public funds.

Out of the total of 7791 off the federal-aid system bridges in Idaho, Oregon, and Washington approximately 1017 are structurally deficient and 1176 are functionally obsolete (Secretary of Transportation, 1989). Structurally deficient bridges are either closed to traffic or are load posted for loads less than considered

adequate for the anticipated level of traffic. Bridges are classified as functionally obsolete typically because the bridge geometry is deficient for the intended use. Examples of functionally obsolete bridges are those with poorly aligned roadway approaches, narrow roadway widths, or hydraulic openings that are too small. In Idaho 40% of the bridges off the federal-aid system require replacement while in Oregon the percentage is 24% and in Washington 22%. Many of the bridges off the federal aid system are county bridges with spans of less than 120 feet.

The engineers responsible for specifying replacement structures have many variables to consider for each design. Numerous materials are available to meet the design parameters. Bridge structures can be constructed of any of the common construction materials: wood, steel, and concrete. Some materials have thousands of years of history such as the masonry arch and log bridges while others have relatively more recent histories such as the prestressed prefabricated concrete bridge. All of these materials and systems have their place for a bridge structure. This research will focus on the criteria that county engineers consider when selecting material for a short span bridge structures.

Literature Review

A review of the literature provides insight into the factors considered for bridge selection. Many articles have been published highlighting how various state and county agencies have approached their bridge replacement programs.

In general a bridge can be divided into the substructure and superstructure. The substructure is that part of the bridge that transmits the loads on the bridge to the bearing soil. The substructure includes the footings, breastwalls or backwalls, wingwalls, bridge seat, piling, and bents (Ritter, 1990).

The superstructure is what a layman normally considers "the bridge" and typically is the most visible part of the bridge. It consists of the parts that cross the clear span such as: the stringers, railings, guardrails/parapets, and decking. The types of superstructures most common in short spans today are the beam, deck slab, truss, and arch (Ritter, 1990).

The choice of construction materials is critical for the function and economics of all elements. Wood, steel, and concrete are the principle materials utilized in the substructure, superstructure, and decking.

Wood

Of the three materials considered, wood by far has the longest history as a bridge material. The earliest forms of "bridges" were logs that naturally fell across clearspans allowing man to cross otherwise impassable areas. Man has modified these early structures to permit greater clear spans and increased loads.

Timothy Palmer a civil engineer from Newburyport, Massachusetts built a 2362 feet long by 38 feet wide wooden bridge 7 miles north of Portsmouth, New Hampshire in 1794 (Ritter, 1990). The bridge consisted of pile trestles for the approach spans and three arched trusses. Palmer is also credited with constructing the first American covered wooden bridge over the Schuylkill River in Philadelphia in 1806. This started a trend which resulted in approximately 10,000 covered bridges being built in the United States between 1805 and 1885 (Ritter, 1990).

This same century saw the rapid growth of the railroads and the resultant requirements for bridges at river crossings. Wood was the logical choice as a building material due to its abundance and the availability of the skilled labor necessary for bridge erection . Truss bridges and trestle bridges were the predominant wood designs during this period.

Even as wood bridge construction reached its zenith in number of structures built, other materials were being considered. Irons were begun to be utilized do to superior shear strength as compared to wood. The first metal bridges were cast iron. However wrought iron structures started to dominate bridge structures by the mid 19th century do to higher shear strengths. By the end of the 19th century steel had replaced wrought iron as the primary bridge material. Additional developments in steel production resulted in ever more economical structures. "By the mid-1930's, steel was less expensive than wood on a first-cost basis and took the lead as the primary bridge material" (Ritter, 1990).

Wood has many properties that make it a valuable material in modern bridge construction. Wood is relatively light per unit of length in comparison to concrete. Wood weighs, depending on species, from 35-60 lbs per cubic foot. Structural lightweight concrete, often used is long bridge decks, is 90-120 lbs per cubic foot of material. The less weight per volume results in wood superstructures with lower dead loads. This factor makes it possible and more economical to utilize smaller substructures. For an entirely new bridge this means savings due to reduced material and construction costs. There are examples in which wood was the most economical alternative for replacement of an substandard bridge because the light dead load allowed use of the existing substructure (Verna, 1983).

Lighter members also enhance the erection of the structure, since smaller construction equipment may be utilized during erection. This is especially important in isolated areas where equipment availability is very limited. Transportation of lighter structural members is also easier and more economical. This factor becomes more critical for more isolated construction sites.

Wood lends itself to bridge systems since elements may be pre-fabricated off site. The relatively light material weight makes is possible to transport large pre-assembled components. The advantage of this is that a large part of the work for the bridge actually takes place off site in a controlled environment. If prefabrication of the components was correct only assembly is required on site. This speeds erection time with resultant reduction in construction costs (Williamson, 1972)

Assembly of a wood bridge often requires only semi-skilled labor. This is especially true when bridges consist of prefabricated components that are cut to required dimensions and pre-drilled for connections. Often times complete assembly only requires simple tools such as torque wrenches.

The resistance of wood to chemicals and corrosive materials has increased interest in its use in bridge construction. The effects of roadway chemical deicing agents on steel and concrete bridges has been shown to reduce the life expectancy of these structures. Barnhart (1987) has noted that nail laminated timber decks in Ohio have lasted an average of 30 - 40 years with minimum maintenance. However, many reinforced concrete decks showed signs of spalling after only 5 or 10 years of attack by deicing salts and required "considerable patching" within 20 years (Barnhart, 1987). As a result the concrete reinforced decks had an average expected life of 30-35 years (Barnhart, 1987). Similar findings have been noted on the 1700 bridge system of Allegheny County, Pennsylvania (Verna, 1980). In some parts of the country the deterioration to concrete decks is so severe that replacement is required after only 15 years (Transportation Research Board Special Report 202). Timber is often an economical alternative solution for deteriorated bridge materials in those sections of the country (Verna, 1983).

Wood is a renewable resource. It is a natural material that blends well with its surroundings, presenting an aesthetically appealing structure. Less energy is required to produce the materials and to erect a wood structure than one built of cast in place concrete (Weyerhaeuser, 1980). The energy required to produce a

construction material may become a major factor in economical considerations for bridge material selection as it did in the early 1970's.

Wood does have limitations that have contributed to its decline as a bridge material. The foremost of these is its susceptibility to decay. It is an organic material and is a food source for a number of decay fungi, microorganisms, wood boring insects, and marine organisms (Muchmore, 1984). This is especially true if the untreated wood is exposed to the elements and allowed to get wet. The functional life of wood is significantly increased if it is kept dry. This was the purpose of the covered bridges of the 19th century. The covered structure was built to protect the timber structure from the deteriorating action of the elements.

Today wood is protected by pressure treating with preservatives such as the oil based: creosote, pentachlorophenol, and copper naphthenate or one of a number of waterborne preservatives (Ritter, 1990). These pressure treatments, if properly performed and if the protective envelope is maintained, can increase the life of a wood structure by a factor of 5 to 10 (Erikson, 1989). Use of some of the chemicals for pressuring wood is becoming more difficult as concern arises over their impact on humans and the environment. These is especially true for pentachlorophenol which has been placed on the EPA list of restricted-use chemicals. This requires that the applicator pass a test administered by the controlling state authorities (Ritter, 1990). Preservation is rarely accomplished in the same location where the member was sawn or fabricated. This

increases the time required for delivery which is often greater than that for a steel or concrete beam.

The strength of wood is dependent on a number of factors. Three of the most important are species, grade, and moisture content. Naturally occurring knots are considered defects and reduce the strength of the wood. Moisture content over the fiber saturation point also reduces its strength.

Dimensional stability is another characteristic that directly and indirectly can have negative effects on bridge structures. The dimensions of wood members are effected in all three axes by moisture content and to a lesser extent by temperature. Sawn lumber will expand and contract depending on moisture content of the wood. The amount of expansion and contraction will vary for the three axes depending on axis orientation to the wood grain. The differential volumetric changes can result in checks and cracks in the wood and contributes to the loosening of mechanical connections.

Mechanically connected timber structures resist impact loads by transferring the load from the point of impact to adjacent parts (Hale,1977). The elastic nature of wood and the characteristic of transferring impact loads has had an negative effect on the utilization of wooden bridges. In particular it has prevented the incorportation of an economical wooden guard into the AASHTO bridge specifications. Lightweight wooden guardrails have been successfully statically load tested in accordance with AASHTO standards. However crash testing for complete AASHTO acceptance has not been performed. Although wooden rail systems meet the performance criteria for rail systems by containing a vehicle upon

impact, the defection of the wooden rails is not within current AASHTO standards (TIBIRC Crossings, 1990).

Wood members must be deeper than steel or concrete in order to carry the same design load. The hydraulic opening of the bridge may be reduced significantly which is unacceptable if flood conditions are critical.

The engineering community relationship with wood structures is not as intimate as that for steel or concrete. Most college curricula emphasize the use of steel and concrete as structural materials but consider wood a material for light framing, as in house construction.

Although sawn lumber and even rough logs are still utilized on low volume roads, most wood bridges today are constructed of engineered wood products. The positive characteristics of wood have been enhanced and the negative characteristics mitigated by pressure treated engineered wood products such as glued laminated (glulams) and laminated veneer lumber (LVL).

Glued laminated members are laminations of 1 to 2 inch nominal strips of wood, oriented so that the grains of all the laminations are parallel. The laminations are positioned according to the intended use of each member. The stronger sections of wood are in the most critical cross sectional area. In the case of a beam, lower grade laminations are placed on the neutral axis and higher grades are placed on the outside laminations. The laminations are bonded together with a waterproof adhesive. These forms of engineered wood members have been in use since the 1940's (Erikson, 1989).

Laminated veneer lumber, as the name indicates, is produced from laminating veneers of wood in much the same way that

plywood is produced. However, unlike plywood where the wood grains in the adjacent veneers have a perpendicular orientation, LVL veneer grains are all in a parallel orientation.

These engineered wood products provide a number of advantages over sawn lumber. Defects that naturally occur in wood, such as knotholes, are not concentrated in one area in engineered wood. They can be distributed throughout the member and placed in areas that will not be subjected to high stress, such as the neutral axis of a beam.

The laminations and veneers are dried to a uniform moisture content prior to fabrication. This prevents much of the dimensional problems noted earlier and allows for greater strength ratings.

Glued laminations and laminated veneer lumber can be manufactured into lengths limited only by the available jig of the fabricator, or for pressure treated members by the size of the treatment cylinder. This is especially critical since sawn lumber is not often available in the sizes required. Glued laminations in excess of 120 feet have been fabricated. Laminated veneer beams have practical limits of about 80 feet (Erikson, 1989).

Creosote treated wood is noted for its use in bridge abutments and bents. The abutments are the structure that support the ends of the bridge and hold back the roadway embankment material. Bents are the intermediate supports for multispan bridges. Wood abutments commonly support the superstucture either by a post or pile structure (Ritter,1990). Sawn lumber or glued-laminated posts transfer the superstructure loads to buried spread footings that are typically made of concrete (Ritter, 1990). Horizontal planks can be

placed behind the wooden posts to form breastwalls and wingwalls which hold back the embankment material. Piles are driven in areas where soils cannot support a buried footing. Pile abutments transfer the superstructure loads through wood piles vice posts on spread footings. Like post abutments pile abutments can be used to elevate the superstructure (Ritter, 1990), and with the attachment of horizontal planks hold back the embankment material.

Wood use in bridge superstructures is almost exclusively restricted to clear spans under 120 feet. The trestle or truss systems utilized in the 19th century are not the most common designs of wood bridges today. Wood superstructures usually are glued laminated simple span stringers with either a transverse glued laminated deck or nail laminated sawn lumber deck.

Glued laminated deck panels are 3 1/8 inches or thicker depending on the spacing between stringers (Weyerhaeuser, 1980). The panels are typically three to five feet wide with lengths set to meet the bridge deck width requirements. The deck panels may be placed with or without any connection between panels. Dowel connections are typically used between panels if the roadway surface is finished with a bituminous wearing coat to provide for better wheel load transfer (Ritter, 1990). Both types of deck panels are often utilized with steel stringers in lieu of the glued laminated stringers (NCRP Report 222, 1980).

Another form of all wood superstructure is the longitudinal deck glued laminated bridge. In this design the deck panels run in the longitudinal direction (the same axis as the clear span and the roadway direction) and support the loads without any additional

longitudinal members. Transverse beams are added to tie the longitudinal panels together and provide distribution of wheel loads. The advantage of this design is that it has less depth and provides greater space between the bottom of the superstructure and the water crossing. This increases the hydraulic opening for flood levels (Weyerhaeuser, 1980).

Prior to the introduction of glued laminated decks, sawn lumber planks and nailed laminated decks were in common use. Sawn lumber planks are pieces of dimensional lumber laid flat and nailed either transversely or longitudinally to the underlying stringers. Nail-laminated decks are made up of dimensional lumber placed on edge so that the wider face is in a vertical orientation. The pieces of lumber are mechanically laminated with nails and then nailed to the stringers . Such decks have lasted as long as 40 years. However, their use, even on roads with light average daily traffic (ADT), has declined significantly. Both decks are not suitable for bituminous wearing surfaces. Loosening of the nails occurs due to vibration, localized wheel loads, and moisture content variations which result in dimensional changes (Peterson, 1987). The loosening of the connections allows individual lumber pieces to deflect beyond the tolerance of the wearing course.

Stressed laminated timber decks are being emphasized by the timber industry. A stress laminated timber deck is similar to a nail laminated deck in that sawn lumber planks are laid on edge and laminated together. However, the planks are held together by the compressive forces of transverse posttensioned high strength steel rods (Sarisley, 1990). This form of decking eliminates nail

laminations which can loosen and also provide an avenue for moisture penetration.

The stress laminated deck system was originally developed in Ontario, Canada and has been included in the Ontario Highway Bridge Design Code since 1983 (Ritter, 1990). The American Association of State Highways and Transportation Officials have adopted a "Guide Specification" for stress laminated timber decks pending approval of the full membership (TBIRC Ritter, 1990).

Woods characteristics and availability make it a very useful building material. It was utilized extensively in this country in the 19th century as a bridge material. Some of the characteristics that have detracted from its continued prominent position as a bridge material have been mitigated by modern wood engineering techniques. Glued laminated and laminated veneer lumber have resulted in stronger structural members that can be produced in long spans. Pressure treatment has increased the service life of most bridges by preventing attack by decay organisms. The extensive use of corrosive de-icing salts with the resultant deterioration of concrete and steel has sparked a renewed interest in the use of wood in bridge structures. Wood appears to be a viable option for short span bridges on the secondary road system.

Steel

The shift to the use of steel as the primary material in bridge superstructures occurred in the early 20th century. The railroad expansion era had a profound influence on bridge construction (Ritter, 1990). Speed of erection was a major consideration in bridge

design and material selection. Initially wrought iron trusses were the most common metal bridges (Heins and Firmage, 1979). However, the heavy train loads imparted on short span bridges required members with high shear strength. The large number of timber and wrought iron bridge failures in the latter part of the 19th century necessitated the use of a stronger material (Heins and Firmage, 1979).

Steel became readily available with the development of the Bessemer process in the early 19th century. This process removed impurities from molten pig iron producing steel. Heins and Firmage (1979) state that the properties of steel are dependent on: "... kind and quantity of alloying elements, the amount of carbon, the cooling rate of the steel, and the mechanical working of the steel such as rolling and stressing." Modern steel mills can produce many different grades of steel. The choice of steel for a bridge depends on its intended use and availability from the mill.

Today, steel is one of the premier construction materials. The following characteristics show some of the advantages and drawbacks to the use of this material in short span bridges.

Strength is the principle characteristic which makes steel a very useful bridge material. Steels most commonly used in contemporary bridge construction have minimum yield points of 36,000 psi (A36), 50,000 psi (A572 G50), 50,000 psi (A588), and 90,000 to 100,000 psi (A514) (U. S. Steel, 1986).

Steel is a predictable and familiar engineering material generally classified into one of three categories: carbon steels (A36), high-strength low-alloy steels (A572 and A588), and heat-treated

alloy steels (A514) (Heins and Firmage, 1979). Designers know the characteristics of a particular grade of steel and can accurately predict its behavior in a variety of conditions. Familiarity of the material is fostered by the extensive exposure in engineering curriculums to the application of steel in construction.

The use of steel is very prevalent in all areas of the construction industry. Fabricators and erectors are well versed in the methods of steel construction. This makes steel a logical choice for a public bridge project that will be bid upon and constructed by a private contractor.

It is possible to produced steel in a variety of shapes. Standard structural shapes are available that are very suitable for short span bridge construction. Godfrey (1975) noted that prefabricated steel bridges in the Pacific Northwest are inexpensive due to their "... simplicity and minimum field work...". As much as possible, steel bridge structures are prefabricated prior to delivery to the site. This results in reduced construction time, shorter duration of road closures, and less construction costs.

All materials have limitations in use and steel is no exception. One of the principle characteristics of steel that detracts from its use is corrosion. The combination of moisture and air cause the oxidation of the steel resulting in the formation of ferric oxide (rust). This process can become sufficiently severe that the structural integrity of some members will be compromised. This process is exacerbated with the use of de-icing salts. In order to prevent corrosion, steel surfaces must be protected with a coat of paint which adds to the total life cycle costs of bridges.

The steel industry produced a low-alloy steel, A588, in the early 1960's. This steel oxidized like any other unprotected steel when left exposed to the elements. However, unlike other steels the initial thin ferric oxide film was supposed to "...remain tight to the steel preventing any moisture penetration and further oxidation" (Heins and Firmage, 1979). However, this has not always been the case as determined by examining the approximately 2000 A588 bridges constructed in the United States (Robison, 1988).

A588 requires a specific combination of moisture and some airborne contaminants to create the protective film (Robison, 1988). If the steel is not subjected to the correct combination it may not create the protective film and continues to corrode. Gary Kasza of the Federal Highway Administration's Portland, Oregon office did a survey in 1986 of 11 Washington state bridges constructed of A588. He concluded that it should not be used in wet climates (Robison ,1988). It appears that this steel is not corrosion free in the relatively wet western counties of Washington and Oregon.

Material availability and cost are two other factors that have reduced the use of steel in the Northwest. Although prefabrication has reduced the initial costs of steel bridges the initial costs of other materials have become even more competitive. Generally there are more concrete plants and precasting yards than steel mills in the northwest. Local raw materials are available and utilized to produce concrete. This reduces production and transportation costs usually making the initial material cost of concrete more attractive.

Short span steel bridges have gone through a number of evolutions before arriving at the common designs in use today. At

the end of the19th century, railroads started to use steel plate girders for short span construction. These girders could be prefabricated and then shipped by rail to the construction site and lifted into place by mobile steam powered railway cranes (U.S. Steel, 1986). The superior strength of steel in comparison to other common materials such as wood or wrought iron made it a highly desired material. With the fabrication of plate girders and the heavy lift capability of mobile steam powered railway cranes steel plate girder bridges became a common railroad bridge design.

The early steel highway bridges consisted of through and pony trusses. Many early bridge sites were very isolated with narrow roads. Heavy lift construction equipment was not available, which necessitated small, easy to handle bridge components (U.S. Steel, 1986). Truss systems were the dominant design because they could be constructed on site with angles and plates riveted together. Other advantages of the through and pony truss were that they required a "...minimum increase in approach grades..." and provided maximum clearance between the bridge structure and potential flood levels (U.S. Steel, 1986). The deck system typically was a nail laminated wood deck. These designs were not an efficient use of material and resulted in high dead loads. However, the light live loads and inexpensive fabrication costs made them a feasible and highly economical design at the turn of the century (U.S. Steel, 1986).

In the early 1920's the first wide-flange rolled beams capable of being utilized in bridge superstructures became readily available. The rolled beams could be assembled faster than plate girders, making them more economical. The increased use of rolled beams

was facilitated by the development of new heavy lift construction equipment and more accessible bridge sites (U.S. Steel, 1986).

Deck systems of either reinforced concrete or timber became widely utilized in conjunction with the rolled beam stringers. Simple span designs consisting of rolled beams with a deck system were in use in the late 1930's "... for spans up to about 70 feet and were sometimes used for spans up to 90 feet" (U.S. Steel, 1986). This signaled the end of the through truss as the predominant design in steel bridges. Today steel trusses are predominantly utilized for temporary bridges or in military applications (Sprinkel, 1985).

Lessons learned about welding during the second world war were applied to bridge construction in post war Europe and then in the United States. Welding resulted in a more efficient use of materials which resulted in smaller dead loads and more economical structures (U.S. Steel, 1986).

Use of prefabricated steel bridge components occurred during the 1950's. Prefabrication increased in the steel industry due to the competitive nature of construction (Elasser, 1972). The use of prefabricated bridge components reduced on site construction time, decreasing labor and equipment costs and bridge closer times.

Today steel continues to be a major component in bridge sub-structures and superstructures. One of the more common superstructures on the secondary road system are steel stringers with concrete decks (Better Roads, 1971; Sachse and Willis,1973; NCHRP Report 222, 1980). These structures can be simple or continuous spans. For span lengths of 40 ft and less non composite beams of A36 are very common (U.S. Steel, 1986). Up to 80 ft. wide

flange beams have been used economically (U.S. Steel, 1986; NCHRP Report 222, 1980; and Taly and GangaRao,1976).

Welded plate girders of composite construction are recommended in the U.S Steel Design Handbook for simple spans greater than 80 ft. In composite construction the concrete deck slab is connected to the steel stringers and becomes an integral part of the beam. It not only functions as the bridge deck but also acts with the steel stinger in carrying bridge loads.

As mentioned previously most bridge elements are prefabricated. These components come in a variety of shapes and sizes. Prefabricated T-shaped units up to 80 ft. long and 6 ft. wide can be used in multiple spans from 50 to 110 ft (NCHRP Report 222, 1980). Rectangular units either 39 ft. 4 in. or 19 ft. 8 in. long are combined for different site conditions and roadway widths (see Figure 1) (NCHRP Report 222, 1980). Spokane Culvert Company produced some 200 bridges from 1968-1975 consisting of plate girders topped with steel bridge planks. They were used for spans up to 100 feet in county and U.S. Forest Service bridges (Godfrey, 1975). Armco Steel Company of Ohio produced a similar design utilizing rolled sections for spans up to 50 ft. Up to 1975, Wallowa County, Oregon had constructed 150 of these steel structures utilizing its own crews (Godfrey,1975).

A review of the literature reveals that steel is primarily utilized in the superstructure. However examples are available of the use of steel in the substructure and decking. Steel H beams can be driven as piles for intermediate bents and abutments with steel

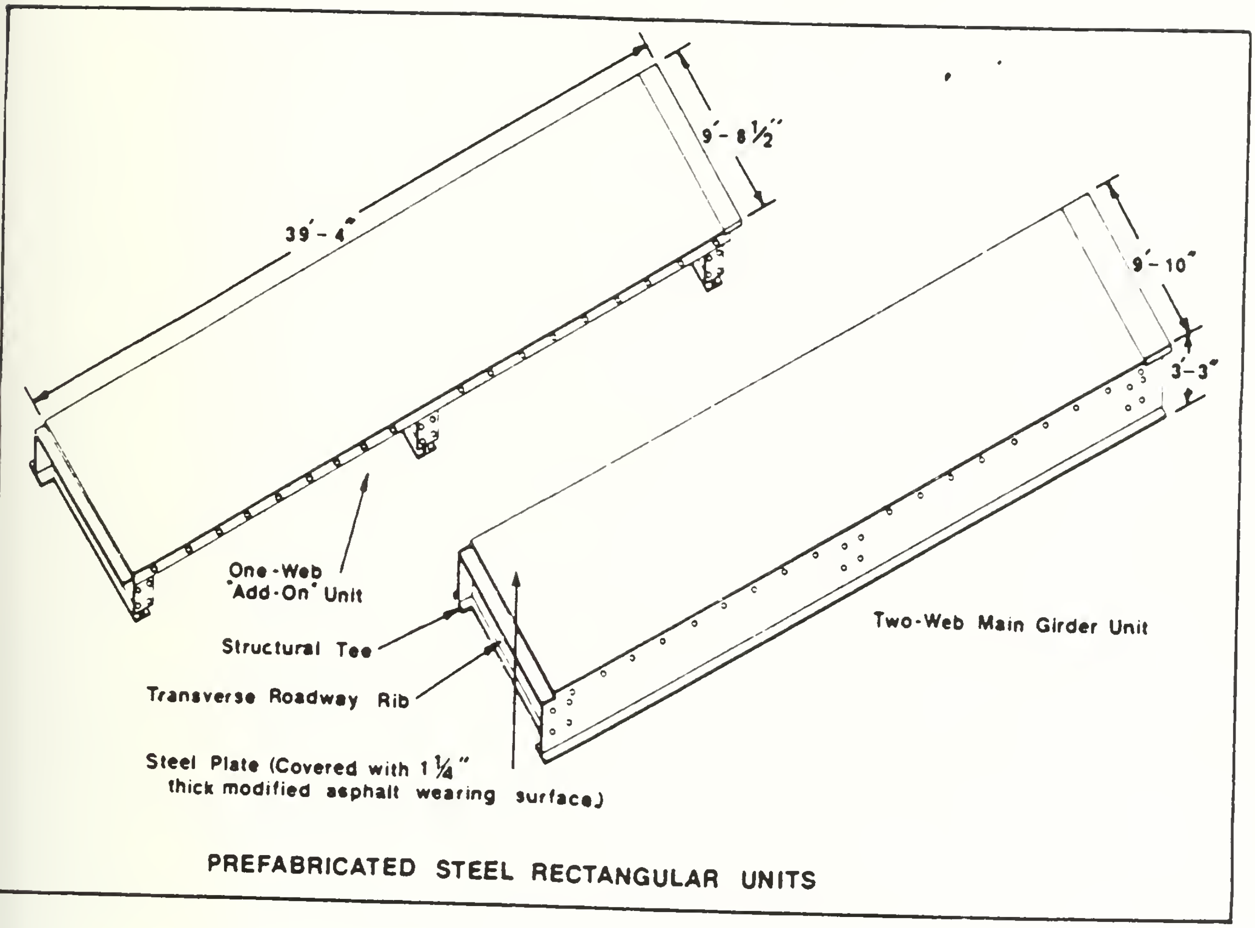


Figure 1. Prefabricated Steel Rectangular Units (NCHRP Report 222, 1980)

sheet piling retaining the embankment material (Better Roads, 1971; and NCHRP Report 222, 1980).

Steel decks usually are either steel grid or orthotropic plates. The primary advantage of these deck structures are that they are light and easy to install (Spinkel, 1985). However the expense of these decks normally do not justify their use in short span structures, particularly in areas of light traffic.

The long span corrugated arch is a system that can be considered both the substructure and superstructure. This system can be utilized for spans from 20-60 feet (NCHRP Report 222, 1980; and Perin, 1973). The use of this system is highly dependent on existing soil conditions and available fill material (Godfrey, 1975).

Steel has a long history of use in bridge construction in this country. It is a very familiar construction material. Certain limitations have to be considered prior to and during its use in bridge structures. Today, prefabricated bridge elements are the standard method of steel bridge construction. Rolled shapes and plate girders are utilized in prefabricated components depending on span length, design, and fabricator. These steel superstructures have been a very viable option in the past in counties in the northwest.

Concrete

Prior to the Roman empire mortar was used in construction . However modern forms of reinforced concrete were not utilized until the late nineteenth century (Heins and Lawrie, 1984). Reinforced concrete bridge structures were pioneered in Europe by Hennebique of France (Heins and Lawrie, 1984).

As early as 1886 prestressed concrete was being investigated. However, it was not until 1926-1928 that the control of the loss of the prestress with high-strength steel made the application of prestressed concrete members practical in construction (Heins and Lawrie, 1984). The use of prestressed concrete girders in bridge construction started in the U.S. 40 years ago with the construction of the Walnut Lane bridge in Philadelphia in 1950 (GangaRao and Taly, 1976). The use and acceptance of precast prestressed concrete in bridge structures has increased as reported by Godfrey (1975) and Sprinkel (1985).

Concrete, in particular Portland Cement Concrete, is one of the premier bridge construction materials. Cast-in-place bridge structures built 65 years ago utilized mix designs that developed compressive strengths of 2000 psi (Pfeifer, 1972). Today modern design mixes, placement techniques, and curing can easily produce high-quality, high-strength concrete of 10,000 psi and greater. This permits designs with long clear spans eliminating intermediated piers and bents. Some precast prestressed sections are capable of 180 foot clearspans (Prestressed Concrete Institute, 1980). The strength of concrete in action with prestressing steel can produce beams with very low depth to span ratios (Prestressed Concrete Institute, 1980). This important characteristic result in maximum hydraulic openings.

In addition to high compressive strength concrete has many other characteristics that make it a desirable construction material. The majority of the weight and volume of concrete is composed of aggregates which typically are produced locally resulting in reduced

production costs. Concrete can be produced in a variety of strengths and weights to suit project requirements. Lightweight concrete can be produced for bridge decks that has a dead load of 85 to 115 pounds per cubic foot (Kosmatka and Panarese, 1988). Fluid concrete is moldable to many shapes providing flexibility in bridge design. Properly mixed and placed concrete is a highly durable material with little fatigue due to its high strength in comparison to low bridge loads. Properly chosen aggregates provide a hard, skid resistant wearing surface. Concrete resists attack by many corrosive chemicals. The thermal properties of properly cured concrete are desirable in bridges, resisting fire as well as freeze thaw cycles. Little to no maintenance is required of concrete bridges. Concrete does not require painting and will not require patching unless some chemical attack produces spalling or cracking.

Problems can develop with any concrete bridge. Poor mix design, improper components, and incorrect placement, finishing, and curing all will contribute to an unsatisfactory concrete bridge. Cracking due to shrinkage during curing or due to high fatigue will allow the penetration of water resulting in reduced service life. Concrete can be susceptible to expansion due to attacks by sulfites present in water runoff or other sources. An excess of trapped water in concrete will result in popping and spalling during freeze thaw cycles. Highly permeable concrete may allow excess moisture to penetrate to reinforcing steel. The resultant rusting and expansion of the steel can result in spalling and other deterioration. These attacks are exacerbated by the use of road de-icing salts (Barnhart, 1987).

Concrete construction is very dependent on weather conditions. Heavy rains will produce complications during the placement, finishing, and curing of concrete bridges. Cold weather is another environmental condition that can hamper if not prevent concrete bridge construction.

Many of the problems noted with concrete can be mitigated or eliminated in the controlled environment of a precast yard. Exact proportioning of mixtures, combined with uniform mechanical consolidation, and steam curing result in high strength, highly impermeable uniform bridge components.

Precast elements are utilized in all the components of a bridge. Concrete piling is very common for substructures. These can be formed and poured on site or precast elements. Precast yards produce abutments and wingwalls that can reduce on site labor (Prestressed Concrete Institute, 1980).

Precast superstructural elements come in many different shapes depending on span requirements and the available forms in local precast yards (see Figure 2). Many of these shapes include an integral decking system. Solid deck slabs are utilized in spans less than 30 feet and voided slabs can span up to 50 feet with the standard AASHTO HS-20 load (Prestressed Concrete Institute, 1980). Channel sections and multi-stemmed sections can be utilized for intermediate spans from 20 to 60 feet while double stemmed sections can span 60 feet and more (Prestressed Concrete Institute, 1980). For longer spans exceeding 100 feet box girders, I-girder sections, single stem sections, or bulb tee sections are available. The bulb tee section is very common in Washington, Oregon, and Idaho

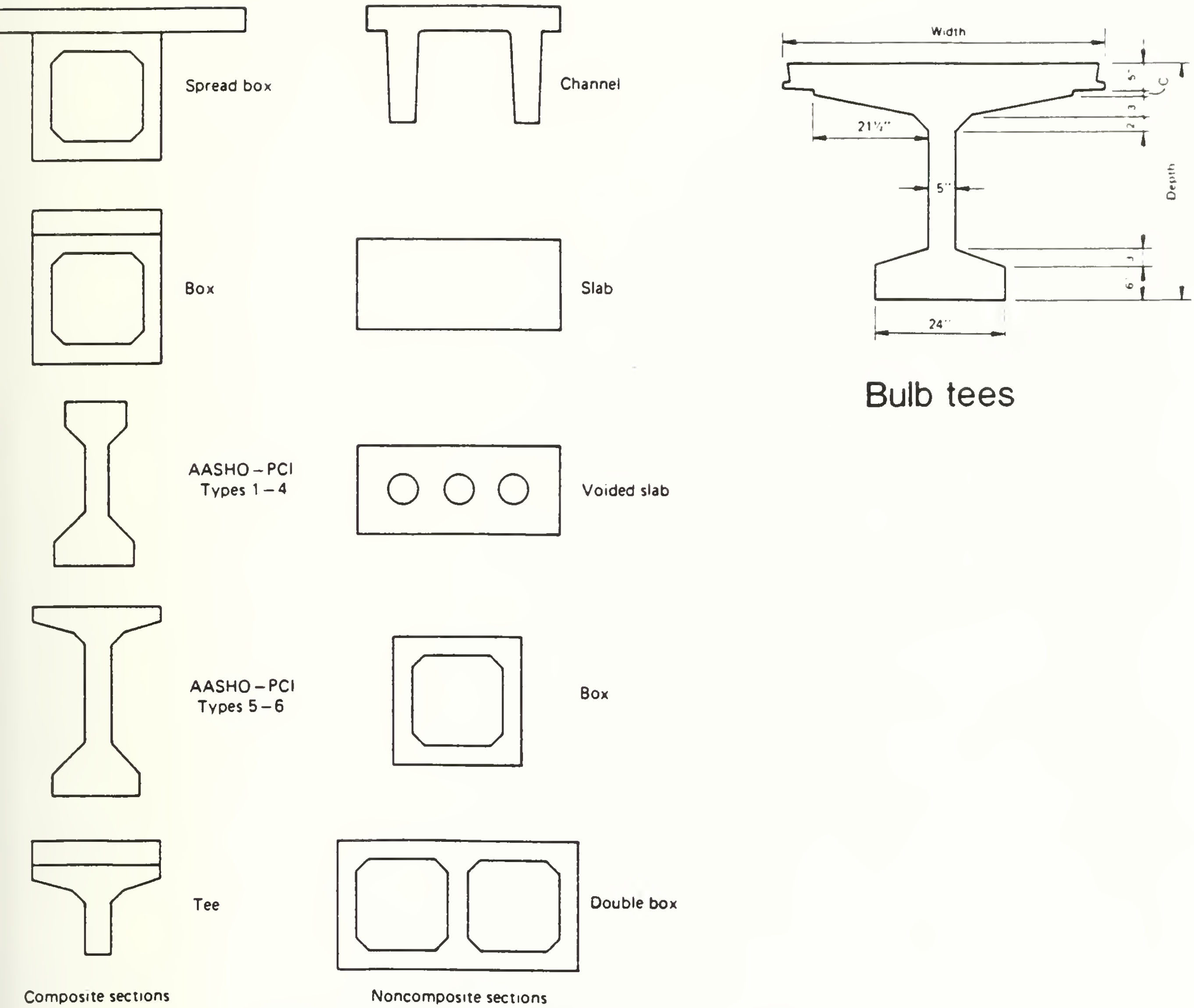


Figure 2. Precast Concrete Element Shapes

(Heins and Lawrie, 1984; Prestessed Concrete Institute, 1980)

(Godfrey, 1975). It is possible to have clear spans up to 180 foot with bulb tee sections (Prestressed Concrete Institute, 1980). As mentioned all of these sections have an integral bridge deck or can have a cast-in-place deck placed on top. This improves the bridges strength and provides a different wearing surface than the precast element.

Precast elements have many advantages over cast-in-place concrete structures. The most important is the more consistent quality of the final concrete that results from the controlled conditions of the precasting yard. In a precasting yard it is also possible to prestress structural elements which provides additional strength permitting longer clear spans. Precast elements can be fabricated and assembled in a shorter period of time than cast-in-place structures.

Modern concrete has been refined to make it a superior bridge material. It has many characteristics that highlight its value in bridge construction. If not properly constructed on site or properly prefabricated in a precasting yard concrete bridge structures may have degraded performance that can be inferior to other materials. Typically this is not the result and concrete construction results in superior bridge structures. This is especially true if precast, prestressed elements are utilized.

Previous Research

A poor bridge management program including negligent inspections resulted in the collapse of the Silver Bridge in West Virginia on December 15, 1967 killing 46 people. The actual cause of

the disaster was the failure of one of the structural eyebars due to "... the joint action of stress corrosion and corrosion fatigue" (Ross, 1984). This disaster has had a ripple effect on state and county bridge programs that continues to this day. Actions in Congress include passing legislation aimed at identifying and rectifying the problems with the nation's bridge infrastructure. Congress initiated the Special Bridge Replacement Program (SBRP) in 1970 authorizing $816.5 million over eight years. Since that first action there have been three modifications to the legislation. Most recently the Surface Transportation and Uniform Relocation Assistance Act (STURAA) of 1987 extended the Highway Bridge Replacement and Rehabilitation Program (HBRRP) authorizing $1.63 billion annually until the end of fiscal year 1991 (Secretary of Transportation, 1989).

The HBRRP allows for federal payment of up to 80 % of the costs of a bridge project. Money is allocated to states by the FHWA in accordance with an apportionment factor. The apportionment factor is the ratio of the states needs compared to the national needs. States needs are defined by a standard sufficiency rating assigned to the bridges on the national bridge inventory. The sufficiency rating is based on the most recent AASHTO "Manual for Maintenance and Inspection of Bridges". Bridges are evaluated for three general categories and relative percentages: structural adequacy and safety (55%), serviceability and functional obsolescence (30%), and essentiality for public use (15%) (Secretary of Transportation, 1989). The greater the number of bridges with low sufficiency the greater the needs of the state.

Funding and emphasis on the national level has generated research into all aspects of bridge programs. Some of these reports provide insight into present practices and utilization of materials in short span structures. In April 1974 GangaRao and Taly (1976) conducted a national survey of short span bridges (75 feet and less). A questionnaire was sent to the "Chief Bridge Engineers" of all 50 states. Useful information was obtained from Idaho and Oregon but only general information was included about Washington state since it was not one of the 46 respondents.

The survey revealed no national standard in bridge construction although the majority of states utilized AASHTO and the FHWA standards as "guiding criteria" for bridge widths. The predominate form of bridge decks were cast-in-place concrete. Timber decking was the only other form of bridge deck mentioned. It was utilized under "special conditions" in Louisiana, Minnesota, and Wisconsin despite its "high material costs" (GangaRao and Taly, 1976). The advantage of the timber decks was the simple installation enabling the work to be accomplished by state crews.

Short span superstructures are almost exclusively "...slab or beam-slab construction." Idaho reported 1 steel girder, 163 prestressed concrete, and 137 reinforced concrete short span bridges built during the 10 year period (1964-1973). Oregon's Chief Bridge Engineer reported 7 steel girder, 220 prestressed concrete, and 173 reinforced concrete short span bridges built during the same time frame (GangaRao and Taly, 1976). It was unclear from the available report documents if these numbers represent all bridges built in the state or only those for which the state agency was responsible. It is

interesting to note that during a similar time frame Wallowa County, Oregon constructed up to 150 prefabricated steel bridges with county crews (Godfrey, 1975). Therefore it is believed that the information from GangaRao and Taly's survey represents bridges constructed only by state agencies. Washington state did not respond to the survey, however; GangaRao and Taly noted that Washington used its own standard prestressed concrete I and box sections for bridge construction (GangaRao and Taly, 1976).

A questionnaire was also utilized in the National Cooperative Highway Research Program Report 222 "Bridges on Secondary Highways and Local Roads Rehabilitation and Replacement". It was sent to the 50 state highway agencies. In addition, site visits were conducted to ten of the state transportation agencies including Washington Department of Transportation and one local transportation agency, the Washington County Road Administration Board. Information, predominantly from the state officials, indicated steel beam bridges were the most common type of secondary highway bridge superstructure in the nation. Following steel beams in order of frequency were timber beams, concrete beams, concrete slabs, steel trusses, prestressed concrete, concrete arch, and box beams. The most common type of structure involved in bridge failures were steel trusses followed by timber, steel beam, prestressed concrete, stone arch, concrete beam, and "others". It is important to note that the two principle causes of failure were believed to be overloading and collision rather than deterioration (NCHRP Report 222, 1980).

Hill and Shirole (1984) examined 3,692 bridge replacements in Minnesota from 1973 to 1983 for spans up to 100 feet. Of this total 1830 were constructed of concrete, 693 of steel , 564 of prestressed concrete, 841 were of timber and the remainder attributed to masonry, wrought iron, and aluminum. They found that in Minnesota there appeared to be a trend away from cast-in-place concrete. The reasons cited were the "... time consuming falsework, formwork, cure, and field quality control for such construction during Minnesota's limited construction season." Prestressed concrete beams were found to be "...15 to 20 percent more economical..." than steel beam superstructures. In addition with the shallow depths of double-T, bulb-T and quad-T precast sections, grading work for the approaches was reduced which eliminated costly site work. One of the noted advantages of steel and timber bridges over concrete structures was that these materials could be constructed year round as opposed to concrete structures which required special considerations during the harsh Minnesota winters (Hill and Shirole, 1984).

Sprinkel (1985) took the results of NCHRP Report 222 and focused on six prefabricated systems believed to be most frequently utilized. The six systems, all constructed of concrete, were: precast concrete slabs, precast box beams, prestressed I-beams, precast deck panels, permanent bridge-deck forms, and parapet and rail systems. He developed a questionnaire that was sent to "most" of the bridge engineers in the fifty states and the District of Columbia as well as other major bridge agencies such as Alberta, Canada. Sprinkel found that the use of prefabricated elements has continually increased and

was predicted to continue. Use of prefabricated elements increased because of reduced first cost and accelerated construction. Sprinkel found that first costs have far greater weight in bridge selection than life cycle costs. However he noted that bridges on low volume roads should be designed to reduce first costs vice maintenance costs. More money may be spent on initial construction than could ever be realized in reduced maintenance costs over the life of the bridge. The inverse is true for high traffic density bridges (Sprinkel, 1985).

The available literature revealed common characteristics considered in bridge material selection. The Prestressed Concrete Institute emphasized the following factors in its publication on selection criteria for short span bridges: "...wide use and acceptance, low initial cost, minimum maintenance, fast easy construction, minimum traffic interruption, simple design, minimum depth/span ratio, assured plant quality, durability, and attractiveness" (Prestressed Concrete Institute, 1980).

Report 222 of the National Cooperative Highway Research Program, ("Bridges on Secondary Highways and Local Roads Rehabilitation and Replacement", 1980) found the following factors universally considered on almost all bridge designs: "... required structural capacity, traffic volume, anticipated future use, labor required for replacement (in-house or contractor), and cost." In addition the report cited other site specific factors with various degrees of importance: experience, available contractors, budget constraints, material availability, and environmental priorities (NCHRP Report 222, 1980).

A value engineering study conducted on the selection of low-volume road bridges (GangaRao, Ward, and Howser; 1988) concentrated on spans of 30, 60, and 100 feet with an average daily traffic volume of less than 200 vehicles per day. This study identified seven criteria as the most important for bridge system selection: "... initial material cost, ease of construction, maintenance, durability, service life, availability of materials, and unit weight of bridge system" (GangaRao, Ward, and Howser; 1988). Twenty eight designs were analyzed and estimated for first and life cycle costs. These costs were noted as a function of six factors: supply and demand for the bridges, familiarity of local contractors with the design, long term performance, ease of erection, maintenance and rehabilitation, inflationary trends of materials used in bridge components, and availability of materials in the local area (GangaRao, Ward, and Howser; 1988).

All of these studies provided a good foundation for research into short span bridge materials in the northwest. They provided insight into what has been accomplished in this field for other geographic locations.

Research Methodology

Many short span bridges are off the primary road system. County public works authorities are primarily responsible for these bridges and were chosen as the primary source of information for this research. Various methods were considered to collect the required information. Phone interviews were considered impractical considering the total number of counties (119) in Idaho, Oregon, and Washington and the restricted time for the study. A survey was considered the most efficient way to gather information on short span bridges.

The maximum length of the survey was limited to three pages with a total of 20 questions. A questionnaire of this length could include all desired questions and could be answered by a knowledgeable county engineer in 15 to 20 minutes. A longer survey would have added limited additional information but would have added additional response time. It was felt the additional time would discourage more officials from responding.

The original questions were formulated into a trial survey. In order to confirm that the research objectives would be met by the questions and that all questions were clear and answerable this survey was reviewed by two Snohomish County bridge engineers. Both engineers were interviewed about the Snohomish County bridge program and short span bridges in general. Then each question in the trial survey was reviewed with them in detail. From these interviews the trial survey was modified to form the final survey (Appendix A). The answers to question eight were modified as a result of the trial survey. Cast-in-place and precast concrete were

combined into the single answer, concrete. This was done to simplify the response. Most county engineers know what material an old bridge is constructed of but do not necessarily know how it was constructed. For all other questions, cast-in-place and precast concrete were considered separately. The literature revealed that cast-in-place and precast have different levels of use because of the different construction techniques. It served the purposes of this research to consider them as separate materials.

The first six questions about staff size and work load, allocation of funds, budget sources, code requirements, number of bridges, and average daily bridge traffic (ADT) were developed to determine if these factors influence material selection. Additionally this information provided background information on each county and the emphasis which each county placed on bridge replacement.

It was desirable to determine what type of materials were used in existing bridges and those proposed for future bridges. Questions eight and nine probed the number of deficient bridges and the characteristics of those requiring replacement. Typically a distinction is made between structurally deficient and functionally obsolete bridges. To simplify the responses this was not done. It was assumed that the number of structurally deficient and functionally obsolete bridges was distributed in the nearly 1:1 ratio as reported by the Secretary of Transportion in 1989.

The objectives of questions ten and twelve were to determine present and future trends in material selection. Question ten focused on future choices and question twelve focused on bridges constructed

in the previous three years. The impact that length of span has on bridge material selection was another aspect of question twelve.

In the literature review, a number of citations emphasized the advantage of erecting wood and steel bridges with "in house" personnel. Question eleven was specifically written to determine how recently completed county bridges were erected.

Costs were a primary focus in most of the literature on bridge repair and replacement. Typically these costs included only those related to the construction of a new bridge. Life cycle costs and user costs were rarely considered in documented bridge costs. The established standard in the literature expressed costs in units of dollars per square foot of bridge deck. Typically these costs were taken from the final price of a construction contract. In question thirteen the average costs for bridges constructed from 1988 through 1990 were requested in units of dollars per square foot of bridge deck.

Material availability can influence material selection. The number and proximity of material suppliers in a region are significant indicators of material availability in a county. This information was requested in question fourteen.

Respondents were requested in question 15 to weight the utilization in bridge substructures, superstructures, and deckings of cast-in-place concrete, precast concrete, steel, and wood. The scale ranged from 1 (low utilization) through (10 high utilization). It was surmized that a comparison of the average answers for each material would provide information on the frequency of use of the four primary bridge materials. Materials receiving higher averages would

be considered the most desired and utilized materials for that bridge component.

Questions 16 through 19 individually focused on one of the subject materials. In each question the respondents were asked to numerically rate one of the four materials on eleven factors. The rating scale ranged from 1 (Disadvantage) through 5 (Advantage). Averages would be determined for the each of the eleven factors for the four materials. It was hypothesized that a comparison of the averages for each factor in each question would provide information on the perceived advantages and disadvantages of each material. A comparison of the averages between the four materials for each factor would provide the relative advantages and disadvantages of each material.

The factors for questions 16 through 19 were: "simple design", "familiarity in the department", "material cost", "material availability", "initial construction cost", "contractors familiarity", "speed of construction", "low maintenance", "durability", "funding availability", and "aesthetics". Ten of the factors were those addressed in prior research and emphasized in the literature. An additional factor, "funding availability", was stressed as being important by the Snohomish county bridge engineers and was included as the eleventh factor. A twelfth answer "others" was included for unanticipated factors.

An explanation is provided to clarify the significance of each factor. The design of a structure varies depending on what material is chosen. The first factor, "simple design", questioned if the design process had any influence on material selection. Some materials are

easier to utilize in bridge design because of simpler connections, more uniform material responses, and more consistent quality of materials.

Often times a material is chosen because it is familiar to the county officials and to contractors that construct bridges. Yet this may not be the best material if all factors are considered. It is possible materials with superior characteristics are not considered because they are not familiar and are not utilized regularly. The queston about "familiarity in the department" and "contractors familiarity" were included to determine which materials were most familiar to the owner and the contractors.

The cost of a bridge is reflected both by the initial costs and other costs extended over the service life of a bridge. How material selection affects the cost of installation of a bridge is reflected by "material cost" and "initial construction costs". It can be assumed, with all other factors being equal, the least costly combination will be the most popular. It was assumed that respondents would consider "in place" material costs including transportation and placement. Indirectly "speed of construction" can also have immediate cost effects although they are not as obvious. Normally, reduced construction time equates to reduced construction costs. In addition faster bridge construction means reduced bridge closer time which reduces user costs. "Low maintenance" and "durability" are important factors effecting the economics of a bridge. Materials that require little maintenance and have high durability will typically be more cost effective for the entire life cycle of a bridge.

"Material availability" is effected by fabrication time, shipping distance, and the number of suppliers within close proximity to the county. Materials that are not available cannot be utilized. Those that are procured from a great distance require transportation costs that typically raise costs and make them less competitive. Long fabrication time may make a material less attractive, particularly if a bridge is "out" and must be replaced expeditiously. A limited number of available suppliers may result in a backlog of orders, reduced competition and increased cost of the material.

There are a number of sources of funding available to local authorities other than county revenues. These funding sources may have requirements that influence a number of aspects of a bridge project including material selection. If a county official desires to use state or federal funding the requirements of the funding source must be fullfilled. For example the Highway Bridge Replacement and Rehabilitation Program (HBRRP) requires that bridges funded under this program must meet HBRRP standards and regulations and when completed must no longer have any deficiencies. Since the HBRRP follows the AASHTO criteria for bridge design any county receiving funding under the HBRRP program must comply with the AASHTO criteria. It is also possible that state statutes stipulate that state funding be provided under the condition that bridge materials be manufactured in state.MILEMARKER

The objective of question 20 was to determine the relative importance various factors had in material selection for bridge substructures and superstructures. This question was formulated so respondents would weigh the importance of each of these factors

independently on a scale of 1 (least important) to 10 (most important). The average of the answers for each factor would be indicative of the more critical factors. Factors with higher averages can be considered more important for superstructure or substructure material selection. The factors were similar to those in questions 16 through 19 except for deleting "familiarity in the department" and "contractors familiarity" and including "total life cycle costs" and "environmental impact". This was done to explore the emphasis material selection has on total life cycle costs and the environment of the bridge site.

"Total life cycle" costs takes into consideration all costs of a bridge over the required service period. This includes initial construction costs, maintenance costs, repair costs, and replacement costs if multiple structures are required for the service period.

During the interview of the Snohomish county engineers it was noted that environmental concerns were having an increasing impact on bridge designs and material selection. This was believed to be particularly true for the substructures. Materials that are not capable of long clearspans require intermediate bents that reduce the hydraulic opening. Environmental concerns focus on pile driving that disrupts the flow of water. Additional concerns include the possibility that substructure materials may leach chemicals due to constant direct contact with fresh water supplies.

After completion of the final twenty questions the survey along with a cover letter were copied in sufficient quantity to mail to the target sample population. County officials in Idaho, Oregon, and Washington were chosen because they were a manageable sample

that would be representative of trends in the northwest. Most previous studies on short span bridges surveyed state highway officials and did not explore county bridge programs. The differences between county and state operating budgets, bridge average daily traffic volume, staff, and maintenance organizations may effect material selection. The counties were considered a more representative sample because the majority of short span bridges are under the jurisdiction of county officials.

Addresses for the counties were received from the Idaho Association of Counties, Association of Oregon Counties, and the Washington Association of County Officials. The survey was mailed to a total of 119 counties in the states of Idaho, Oregon, and Washington comprised of 44 county clerks in Idaho, 36 public works officials in Oregon, and 39 public works officials in Washington.

From the returned surveys, the raw data was entered on a spreadsheet to facilitate the analysis (Appendix B). In addition the data for questions 1 through10 and 15 through 20 were analyzed with the use of the microcomputer version of the Statistical Package for the Social Sciences (SPSS/PC+) software (see Appendix C). This enabled analysis of the frequencies of answers to individual questions. The low responses to questions 11 thru 14 did not justify the use of the SPSS/PC+ program for analysis of these questions.

Results

Out of the 119 surveys sent, 50 were returned for an overall response rate of (42 %). The breakdowns by state are: 27 responses (69 %) from Washington, 16 responses (43 %) from Oregon, and 7 responses (16 %) from Idaho, (Appendix D). The high response from Washington counties may be attributed to a closer identification with the university conducting the survey. Typically for surveys, higher responses are anticipated when the survey is addressed to an individual. For the counties in Oregon and Washington the surveys were addressed to a specific individuals who was either the county engineer, public works director, road master, or bridge engineer. The surveys were addressed to the "county clerks" for the counties of Idaho since the names of public works directors were not available. This resulted in the lowest response from the counties in Idaho.

Of the 50 returned surveys two were blank (one from Washington and one from Idaho) because neither county was responsible for any bridges. This resulted in a total of 48 completed surveys with usefull information. However the total responses varied for each question because some of the 48 respondents did not answer all of the questions. Those questions for which information was not provided were reflected in the raw data as blanks (see Appendix B) and in the SPSS input as a 9 or 99 (see Appendix C). Questions 1 through 10 typically had 46 to 48 useable answers. Questions 11,13, and 14 were answered by approximately half of the respondents. Question 12 had 43 useable answers. The questions that rated material utilization and factors in material selection (questions 15-20) had between 38 and 40 useable answers.

The majority of the counties 41 (82%) did not have a full time bridge engineering staff. Seven counties had a staff that typically consisted of a single engineer whose time was split between bridges and other responsibilities. These seven counties either contained or were in close proximity to a large population center. One of the larger Washington counties, large in terms of number of bridges, budget, and traffic density, had three full time bridge engineers. However that county was the exception when compared to the other county responses.

The majority of the counties (77%) spent between 1 and 75 thousand dollars on bridge repairs. One county had a repair budget of 1.5 million dollars. Almost half (49%) of the counties spent from 30 to 200 thousand dollars on bridge replacement. The replacement budgets of the other counties ranged in 50 to 100 thousand dollar increments, from 250 thousand dollars up to the largest replacement budget of 2.0 million dollars. Eight of the respondents did not have any money budgeted for replacement.

The majority of the money available for bridge replacement came from the federal government (Table 1). More than half of the respondents (24 out of 43) received 75 to 80 % of bridge project funds from the federal government. Thirty five (81%) of the respondents received some amount of federal funding. In most cases the next largest portion of a bridge project was contributed by the county responsible for the project. Counties have provided between 10 and 100 % of the funds of bridge projects. However; 67% of the respondents have provided no more than 25% of the costs of a project. Washington, Oregon, and Idaho provided varying

TABLE 1. Number of Counties that Receive Federal, State, and Local Funding for Bridge Replacement

Percentage of Funding:	Federal	State	County
0%	8 (18%)	26 (61%)	2 (5%)
1-19%	2 (5%)	10 (23%)	8 (18%)
20%	2 (5%)	1 (2%)	14 (32%)
21-79%	12 (28%)	4 (10%)	14 (32%)
80%	19 (44%)	1 (2%)	0 (0%)
81-100%	0 (0%)	1 (2%)	5 (13%)
Totals	43	43	43

degrees of financial support. Washington state provided relatively little funding for bridge replacement. The majority of the Washington respondents indicated a typical funding apportionment of 20% County and 80% Federal. Oregon counties also reported only a nominal amount of state funding. The counties in Idaho recorded the highest amounts and frequency of state support.

Fifteen years ago short span bridges were not constructed to any national standard (GangaRao and Taly, 1976). Today, the AASHTO bridge specifications are the most common standard. According to this survey 24 respondents (54%) utilized AASHTO codes and an additional 9 (20%) used the AASHTO codes in conjunction with state requirements. Of the remainder, 10 utilized state codes and one indicated it followed FHWA requirements.

The counties were responsible for a total of 4584 bridges. The number of bridges in each county jurisdiction varied from zero to 350. The majority of the counties were responsible for less than 100 bridges. As expected, the majority of the bridges had low average daily traffic (ADT). The breakdown of the number of bridges by traffic volume is as follows:

*2928 low volume bridges (less than 400 ADT) (70%)

*1000 bridges with ADT between 400 and 2000 (24%)

*233 bridges with ADT greater than 2000 (6%)

Most counties (42) had at least one low volume bridge. Only 25 of the counties reported having at least one bridge with traffic volume over 2000 ADT. Almost half (112) of the bridges with ADT greater than 2000 were in four counties that contained or were near a large population centers.

Table 2 is the distribution of bridges requiring replacement by state and principle construction material. A total of 762 (16.7%) bridges were deficient or obsolete. Twice as many wooden bridges (402) were in need of replacement than concrete (187) or steel (173). In addition a greater number of counties had wooden bridges that were in need of replacement than counties that had concrete or steel bridges in need of replacement. In general, counties that had at least 15 wooden bridges requiring replacement also had the highest percentage of low traffic volume bridges. This indicates that more wooden bridges are utilized in couties with lower traffic volumes.

Deficient bridge lengths varied from under 30 feet up to 160 feet. The distribution of deficient bridges is as follows:

*number of bridges with a length less than 30 feet---210 (35%)

*number of bridges between 30 and 60 feet----------185 (30%)

*number of bridges from 61 feet up to 120 feet-------211 (35%)

The total number of deficient bridges was less than previously reported because some spans were longer than 120 feet and some respondents did not answer this question.

The respondents indicated approximately 121 new bridges were built or were under construction from 1988 thru 1990 (Table 3). Concrete was utilized in three out of four of the bridges. For spans under 30 feet wood and precast concrete were utilized. The utilization of wooden bridges dropped off significantly above 30 feet. Steel was utilized in the midrange, 30 to 60 feet, then dropped off for longer spans. In the longest range, 60 to 120 feet, concrete, especially precast elements were used almost excusively. One county

TABLE 2. Number (and percentage) of Deficient Bridges by State

Material	Washington	Oregon	Idaho	Totals
Concrete	136 (31%)	18 (8%)	33 (37%)	187 (24%)
Steel	118 (27%)	29 (12%)	26 (29%)	173 (23%)
Wood	188 (42%)	184 (80%)	30 (34%)	402 (53%)
Totals	442	231	89	762

Note that information regarding the number of existing bridges of each type of material was not obtained in the survey.

TABLE 3. Number and Percentage of Bridges Constructed or Under Construction (1988-1990)by Length

Material	Less than 30 ft.	30 to 60 ft.	61-120 ft.	Totals
Precast	9 (38%)	23 (53%)	45 (83%)	77 (64%)
Cast in Place	2 (8%)	6 (14%)	6 (11%)	14 (11%)
Steel	0 (0%)	12 (28%)	2 (4%)	14 (11%)
Wood	13 (54%)	2 (5%)	1 (2%)	16 (14%)
Totals	24 (20%)	43 (35%)	54 (45%)	121

indicated that precast concrete beams were used on six 160 foot spans..

Precast concrete will continue to be the dominate short span bridge material. Four out of five new short span bridges will be constructed of precast concrete (Table 4). Only a few counties in Washington state will use steel or wood for future bridges. Counties in Oregon indicate the number of steel and wooden bridges constructed will small compared to concrete structures. The counties in Idaho seem more flexible in the choice of bridge material.

Question eleven proved to be ambiguous, since there are two possible ways of interpreting the question. The question was intended to request the percentage of <u>all</u> new bridges constructed by contract or county crews. For example the responses from one county in Washington indicate 80% of all new bridges were precast concrete constructed by contractors, 5% were steel constructed by contractors, 10% were precast concrete constructed by county crews, and 5% were wooden bridges constructed by county crews (see Appendix B). This interpretation of the question reveals the most information about the proposed materials and methods of bridge replacement. However the majority of the counties interpreted the requested percentage to be for each material. As an example one county indicated that 100% of the cast-in-place, 100% of the precast concrete, 100% of the steel, and 75% of the wooden bridges will be constructed by contractors and 25% of the wooden bridges will be constructed by county crews (see Appendix B). In either case a review of the answers indicated the majority of new bridges typically will be contractor built precast concrete structures. The

TABLE 4. Principle Construction Materials for New Bridges

Material	Washington	Oregon	Idaho	Totals
Precast	315 (90%)	152 (81%)	27 (36%)	494 (80%)
Cast in Place	21 (6%)	3 (1%)	26 (36%)	50 (8%)
Steel	3 (1%)	16 (9%)	15 (20%)	34 (6%)
Wood	11 (3%)	16 (9%)	7 (8%)	34 (6%)
Totals	350 (57%)	187 (31%)	75 (12%)	612

counties that do utilize "in house" personnel typically will construct wooden bridges. A small number of precast bridges may be constructed by county personnel.

Most of the cost information was for precast concrete bridges indicating that it was the most common bridge material (see Appendix E). Bridge project costs varied a great deal due to the effect of site conditions. A comparison of material costs within counties indicated that wood was the least expensive bridge material followed by precast concrete. Averages for each material are presented in Table 5. The averages are deceptive because they are based on relatively few responses and a small number of bridges. However individual county costs can be compared to the average costs to determine if the bridge costs for that county are comparitively high. Only half of the respondents provided information on bridge material suppliers. Comments made by the respondents indicated that the degree of confidence confidence in the answers decreased as the distance in the question increased. Respondents either knew the number of suppliers in the local area (< 10 miles) or made educated estimates. However, as the distance increased up to 200 miles, respondents had less information and made less accurate estimates (Table 6). Most of the county bridges are replaced by contractors and it can be assumed that county officials do not procure the bridge materials. Rather, contractors are responsible for procurement of the specified material under the conditions of the construction contract.

To determine the future use of cast-in-place concrete, precast concrete, steel, and wood in substructures, superstructures, and

Table 5. Average Costs in Dollars per Square foot of bridge deck.

Cast-in-Place Concrete

1988	1989	1990
$70.00 (4 responses)	$65.60 (5 responses)	$112.5 (2 responses)

Precast Concrete

1988	1989	1990
$60.24 (15 responses)	$92.87 (15 responses)	$91.71 (10 responses)

Steel

1988	1989	1990
$90.33 (3 responses)	$89.00 (4 responses)	$72.50 (2 responses)

Wood

1988	1989	1990
$30.00 (4 responses)	$62.20 (5 responses)	$49.00 (4 responses)

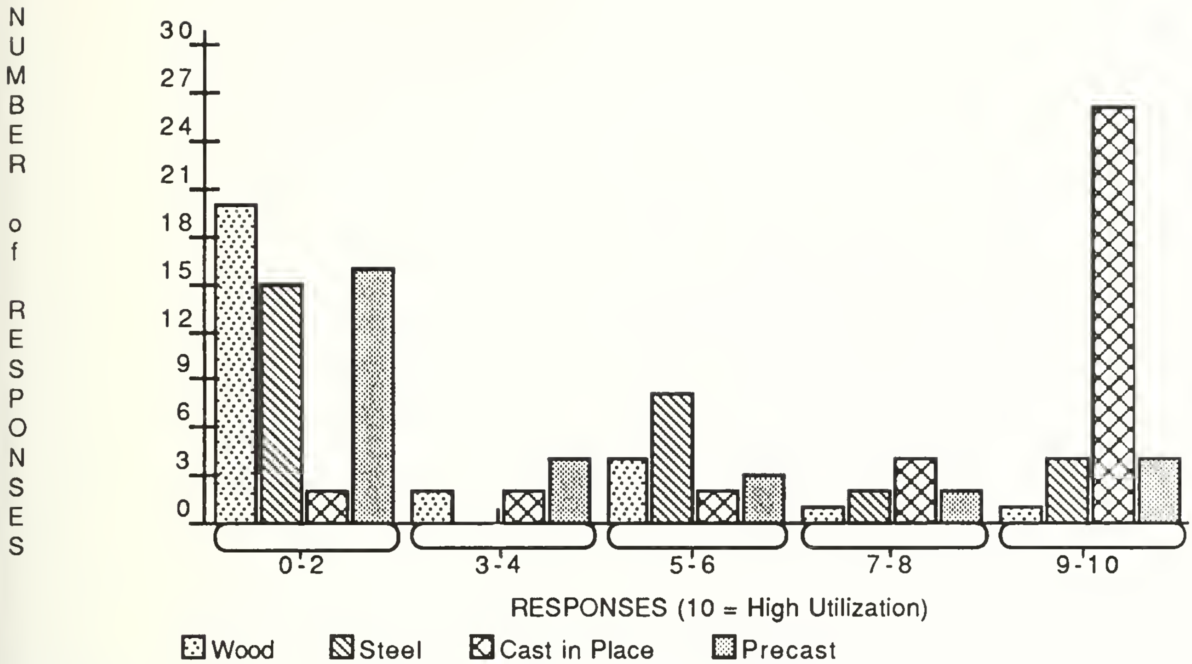
TABLE 6. Estimated Number of Material Suppliers

Material	Less than 10 mi	10 to 100 mi.	100-200 mi..
Precast	2	38	38
Cast in Place	28	57	26
Steel	3	23	21
Wood	9	35	27

decking county officials were requested to rate the subject materials on a scale from 1 (low utilization) to 10 (high utilization). The most highly utilized material in the substructure will be cast-in-place concrete (Figure 3). Precast concrete will be the most utilized material in the superstructure (Figure 4), and decking (Figure 5). Steel will rarely be used for decking and only five respondents indicated it will have limited future application in substructures and superstructures (Figures 3, 4, and 5). Wood will rarely be utilized in the substructure and only four respondents indicated that it would be utilized in the superstructure (Figures 3 and 4). Similarly only four respondents indicated that wood will be utilized for bridge decks (Figure 5).

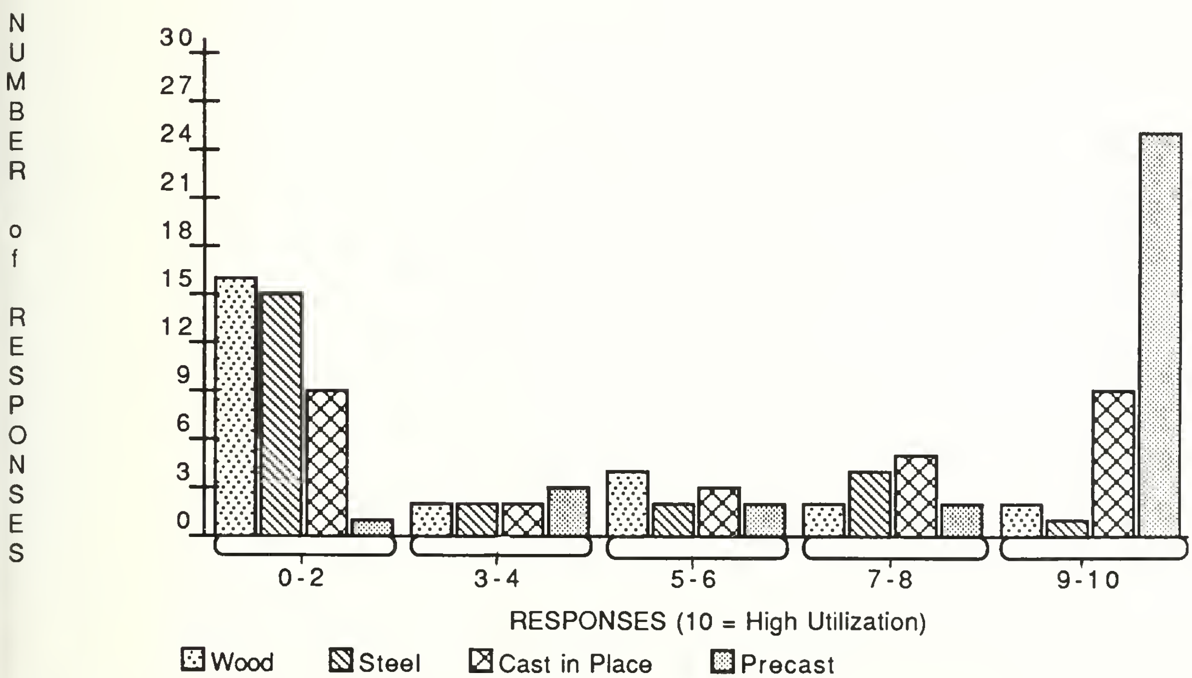
The advantages and disadvantages of cast-in-place concrete, precast concrete, steel, and engineered wood were rated on a scale from 1 (disadvantage) to 5 (advantage). The responses are presented as bar graphs in Figures 6 through 16. Average responses for each factor are shown on the bar graphs under the material keys. Examination of these bar graphs reveals the relative advantages and disadvantages of each material. It is apparent that precast concrete, with the highest average answers for nine out of eleven factors (see Table 7), dominates all the other materials. Only cast-in-place concrete is considered a more available material and wood a more aesthetically pleasing bridge material.

Both low maintenance and durability are important factors for the selection of both substructure and superstructure materials. Precast and cast-in-place concrete exhibit lower maintenance and



verage Values: 2.29 3.66 8.53 3.31

Figure 3.
Utilization of Materials in the Substructure



verage Values: 2.96 3.17 5.61 8.58

Figure 4.
Utilization of Materials in the Superstructure

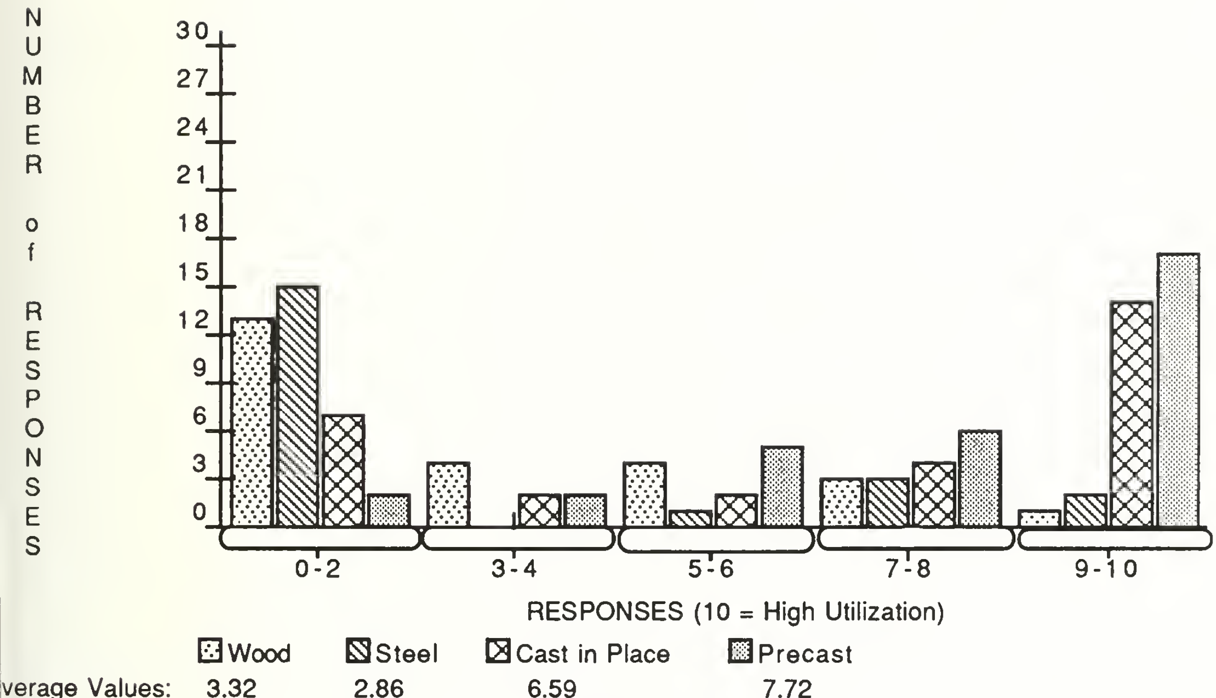


Figure 5.
Utilization of Materials in the Bridge Deck

TABLE 7. Averages for the Prioritized Material Selection Factors

Priority	Material Selection Factors	Engineered Wood	Steel	Cast-in-Place Concrete	Precast Concrete
1	Low Maintenance	2.1	2.27	4.09	4.37
2	Durability	2.07	3.12	4.22	4.28
3	Construction Costs	3.49	2.66	2.91	3.53
4	Material Cost	3.41	2.61	3.27	3.63
5	Material Availability	3.51	2.98	4.13	3.67
6	Speed of Construction	3.59	3.22	2.41	4.57
7	Simple Design	3.54	2.95	3.41	4.09
8	Familiarity in Dpt.	2.9	2.54	3.42	3.79
9	Contractor Familiarity	2.88	2.78	3.77	3.87
10	Funding Availability	2.88	3.05	3.42	3.55
11	Aesthetics	3.59	3.02	3.3	3.53

Scale for Answers 1= Disadvantage, 3=Neutral, 5= Advantage

have higher durability in comparison to wood or steel (Table 7, Figures 6 and 7). These factors have a substantial influence on the engineering economics of a structure. As mentioned previously the importance of these factors is magnified since counties typically fund all maintenance costs.

The differences in the maintenance and durability of concete, steel, and engineered wood can be attributed to material properties. Corrosion diminishes the durability of steel necessitating painting. A number of counties commented in the survey that the painting requirement of steel increased maintenance costs which eliminated it as a bridge material. Although treated wood does not require painting, maintenance costs for wooden bridge in general were still considered too costly by the respondents. Comments in the survey indicated that more frequent inspections were necessary with wooden bridges to insure that all connections remained tight. It was felt that engineered wood was subject to deterioration and was not considered as durable a material as concrete or steel. County officials stated it was "...difficult to detect deterioration" in a wooden structure. One official preferred to use wood more often but did not because of the lingering concerns about longevity. Another official commented that the "...costs were high relative to life" and that wooden bridges were not much cheaper than concrete. The difference in maintenance and durability between precast concrete and cast-in-place concrete is explained by the differences in the final quality of the material. The controlled environment of a precast yard usually results in a higher quality product than can be produced with concrete placed under field conditions.

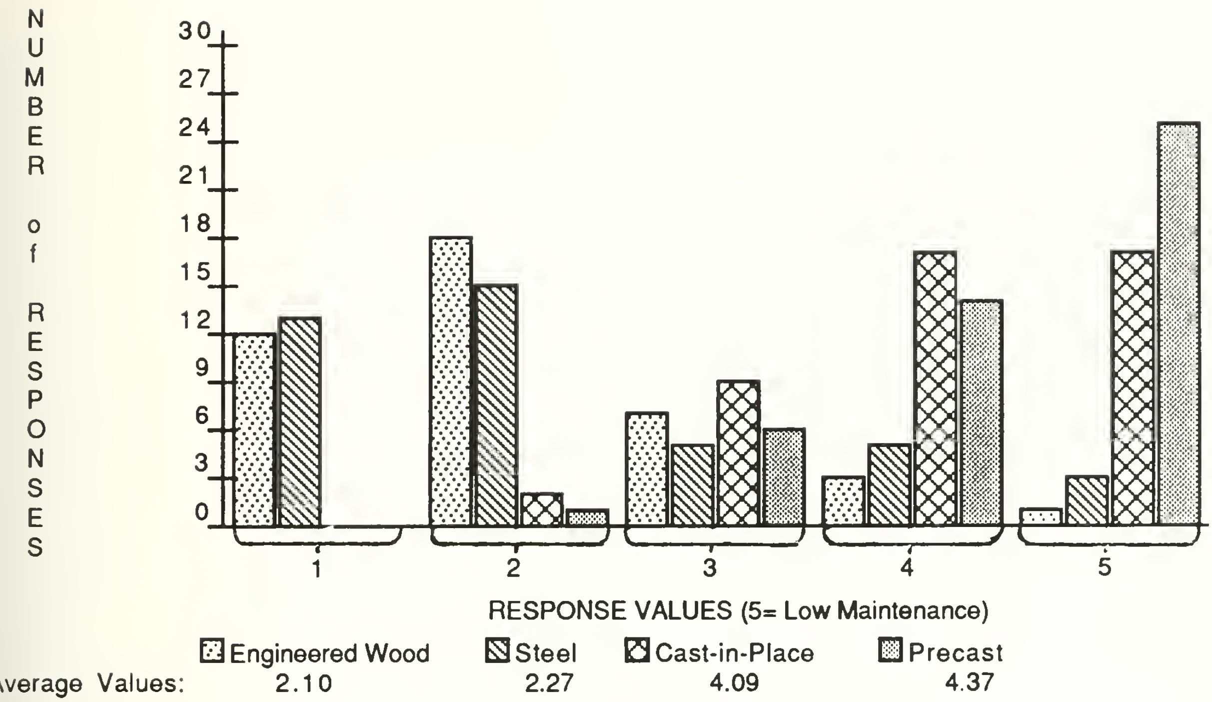


Figure 6.
Comparison of Required Maintenance

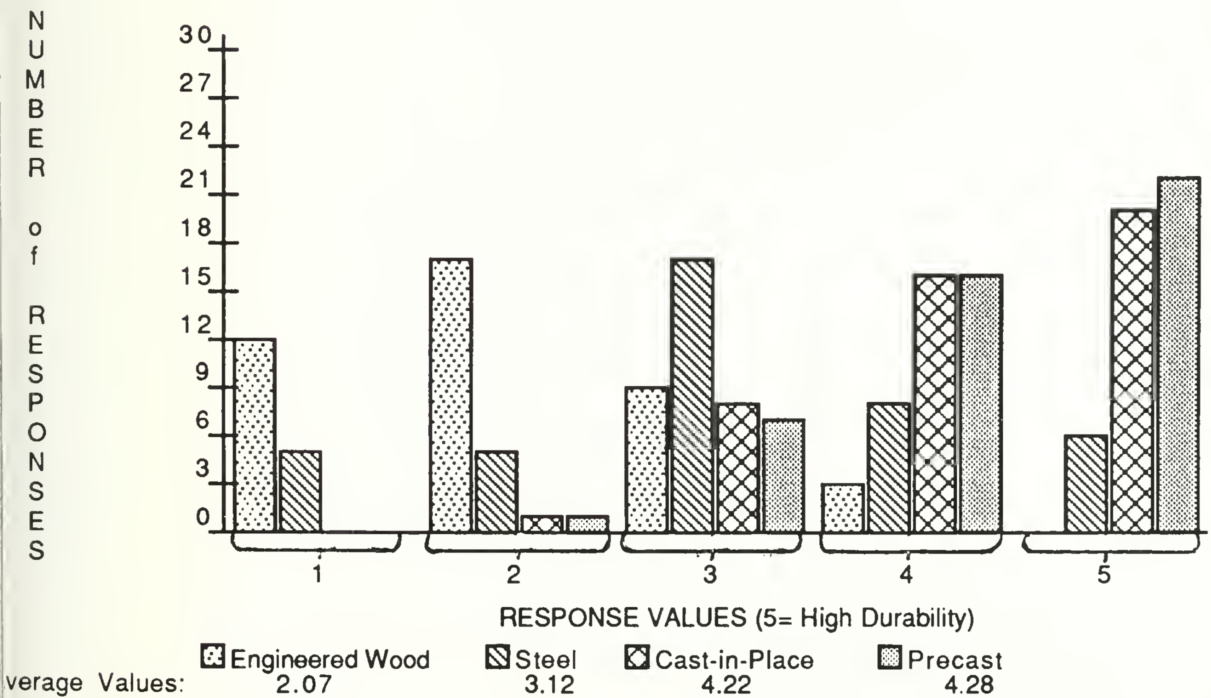
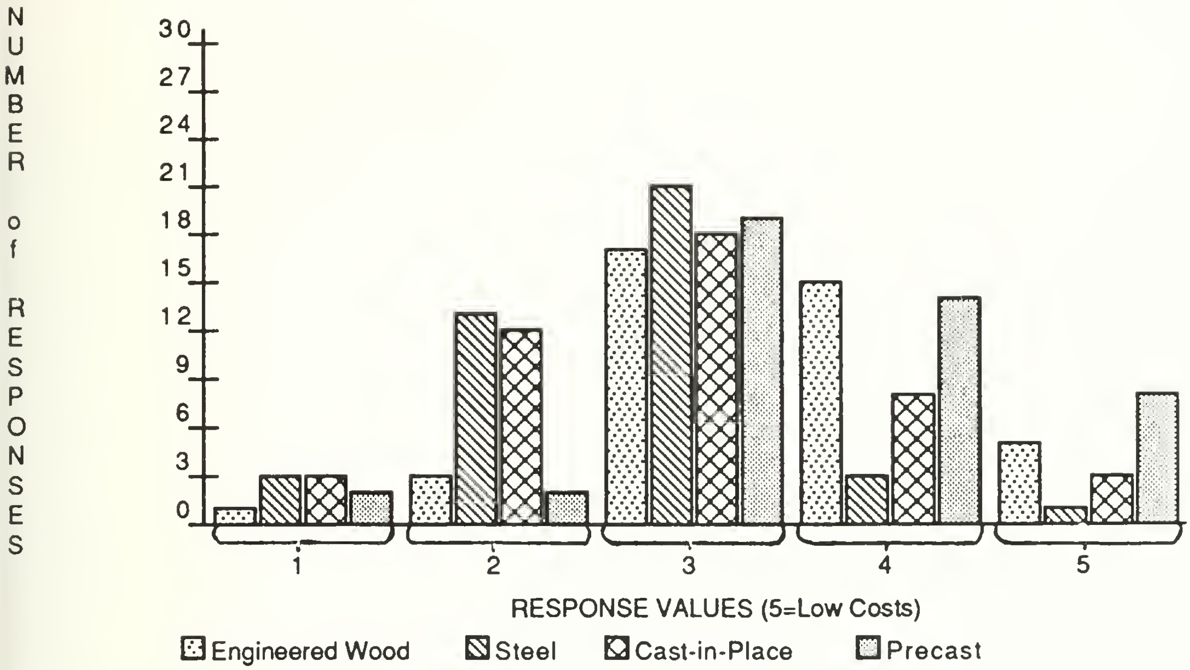


Figure 7.
Comparison of Material Durability

The next most important factor was construction costs (Table 7 and Figure 8). Here there is a marked difference between precast and cast-in-place concrete. The higher average for precast concrete indicates that the prefabrication of bridge components greatly reduces construction costs. One county noted that the trend has been away from cast-in-place concrete because of the time required for formwork, the fact that falsework can interfere with stream flows, and the poor quality of the finished concrete.

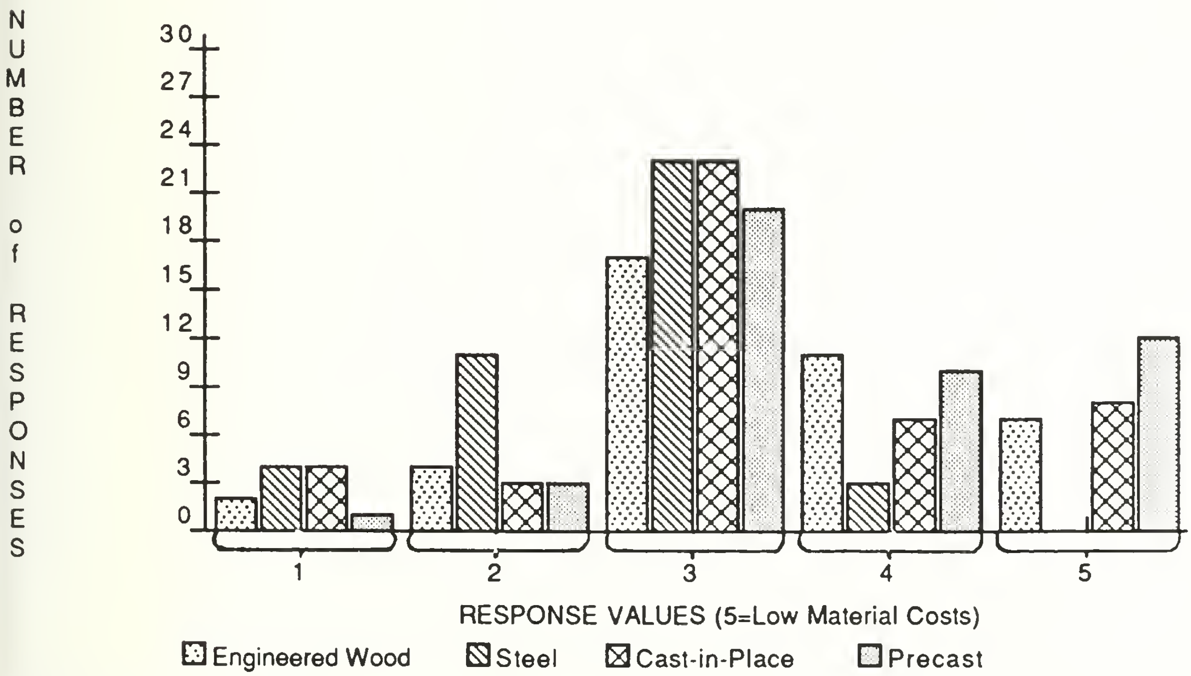
Material cost is one of the major components of construction costs. Some respondents may have considered these factors too closely enmeshed to be able to distinguish them individually. This is most evident by noting the neglible difference in the average answers for "construction costs" and "material cost" for steel in Table 7 and Figures 9 and 10. Steel has high construction costs which is partly due to low material availability and high material cost. Conversely precast concrete and engineered wood had the lowest construction costs and were the least expensive materials. Cast-in-place concrete appears to be a more expensive material than precast concrete and engineered wood even though it is considered the most available material (see Table 7 and Figures 9 and 10). It appears that respondents typically consider "in place" material costs such as placement and finishing for cast-in-place concrete which includes labor costs. This would make cast-in-place concrete a more expensive material.

Speed of construction can be expected to have a direct relationship with the cost of construction and the availability of material. Materials that can be constructed in a shorter period of



Average Values:	3.49	2.66	2.91	3.53

Figure 8.
Comparison of Construction Costs



Average Values:	3.41	2.61	3.27	3.63

Figure 9.
Comparison of Material Costs

time can have lower construction costs. Projects will be completed in a shorter period of time if material is readily available. Precast concrete and engineered wood both are readily available and have relatively lower construction costs (Figures 8 and 10). As predicted they also have the shortest construction times (Table 7 and Figure 11). Conversely cast-in-place concrete appears to have the longest construction time. This is not due to long lead time in procurement or material characteristics, rather it is due to construction methods. A great deal of time is required to build the forms; install the reinforcing steel; place, finish, and cure the concrete; and finally strip the forms.

The design of a structure and how familiar the material was to county officials and contractors did not have the same economic emphasis as the previous six factors and therefore was not as critical in material selection. County officials felt concrete design was familiar both in the department and to contractors who bid upon county contracts (Table 7, Figures 12, 13, and 14). Steel designs appear to be more complex. Steel is not as familiar to county engineers and contractors as concrete (Table 7, Figures 12, 13, and 14). It appears that with the increased utilization of precast concrete county officials have not considered short span steel bridges and have become unfamiliar with the material.

Replacement of county bridges are funded to a large degree from sources outside county revenues. The federal government is the primary source of funding. Funding is readily available for concrete bridges and to a lesser extent for steel structures. It appears that more respondents felt that less funding was available

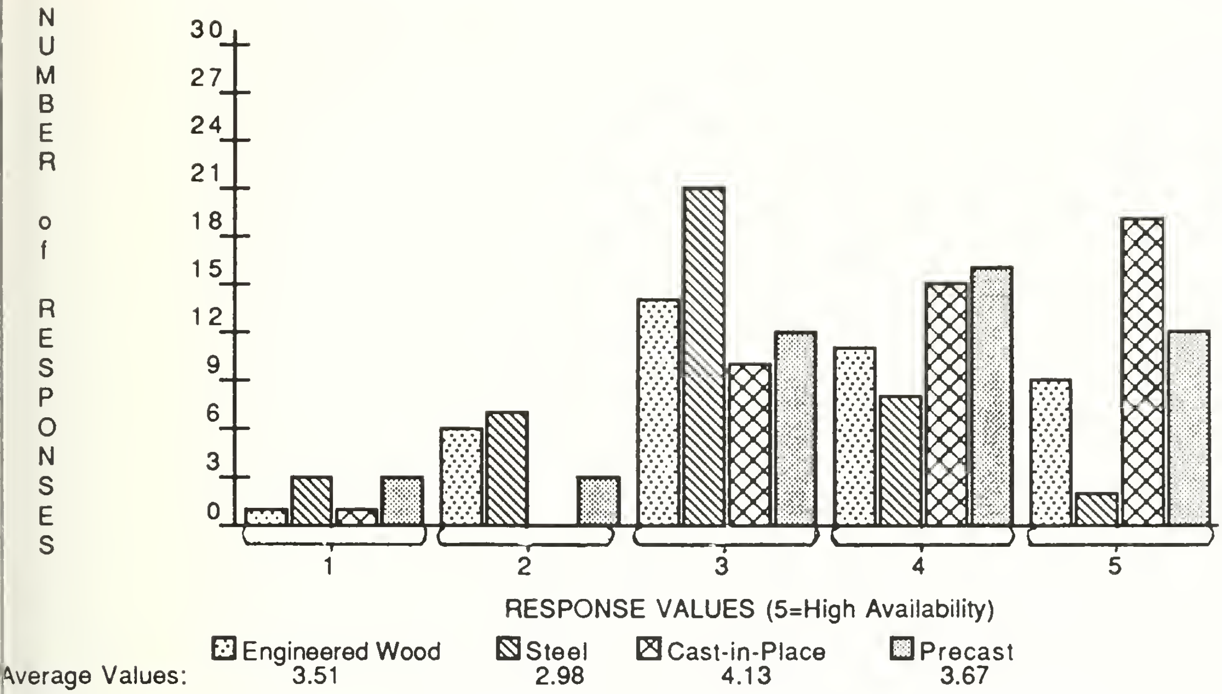


Figure 10
Comparison of Material Availability

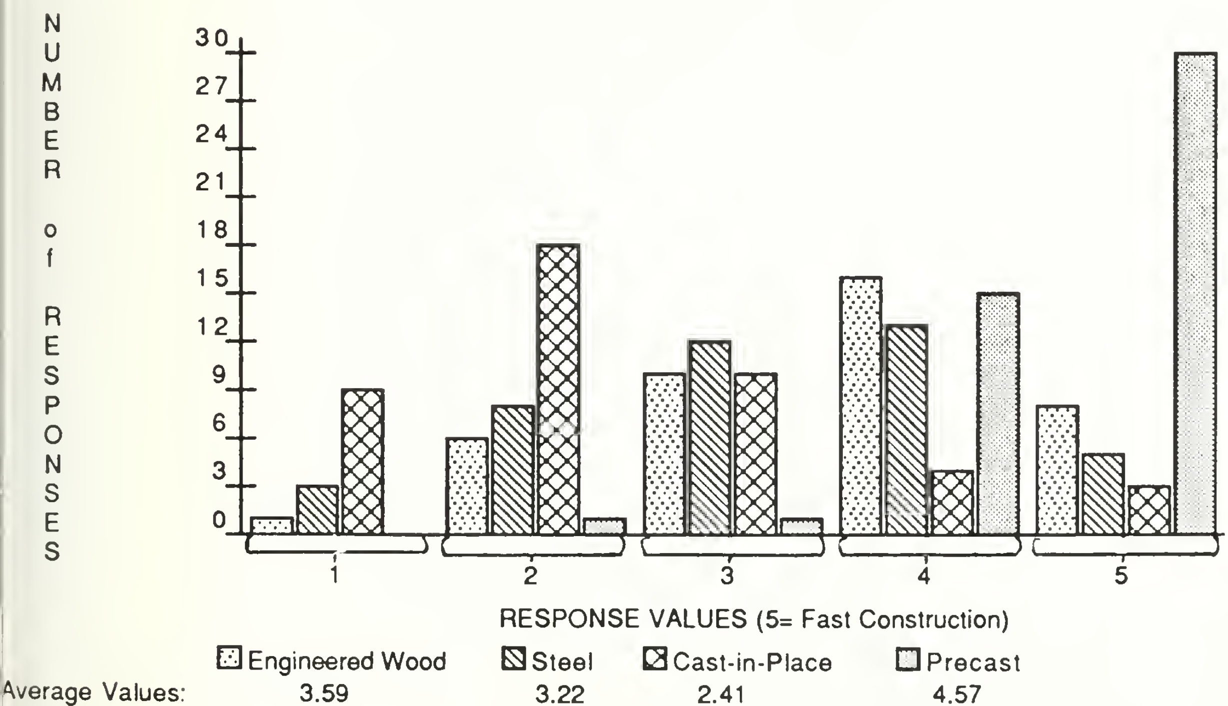


Figure 11.
Comparison of Speed of Construction

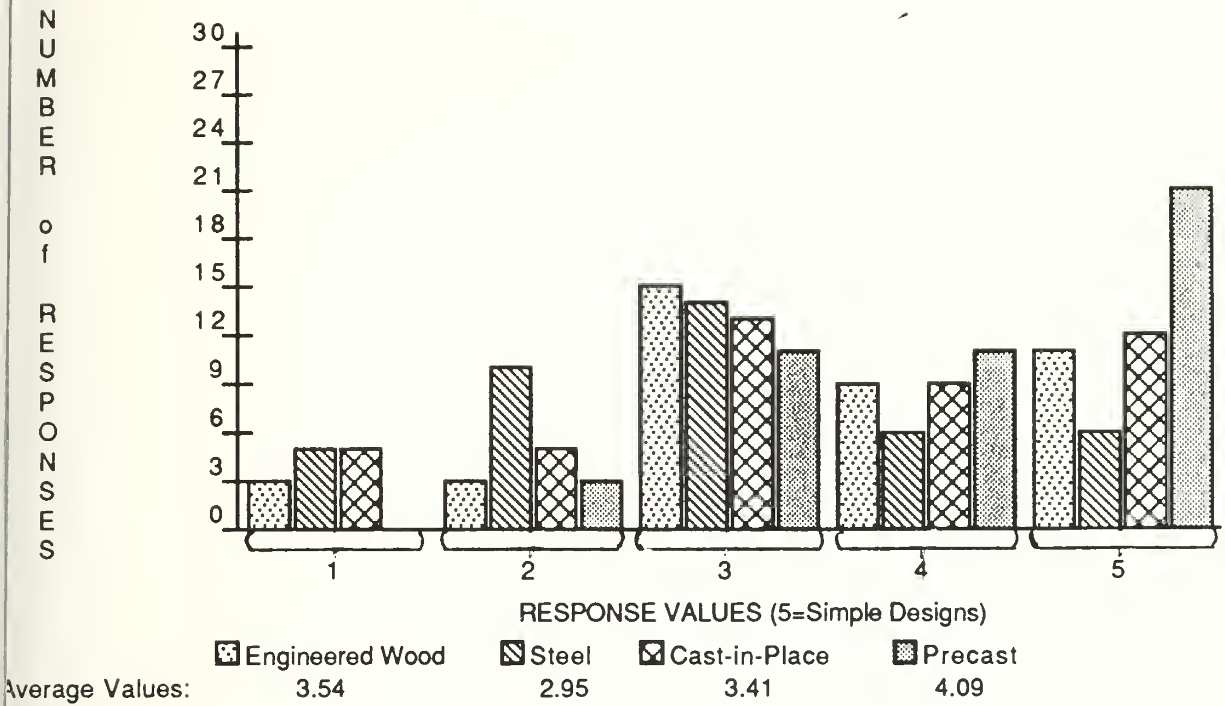


Figure 12.
Comparison of Design Complexity

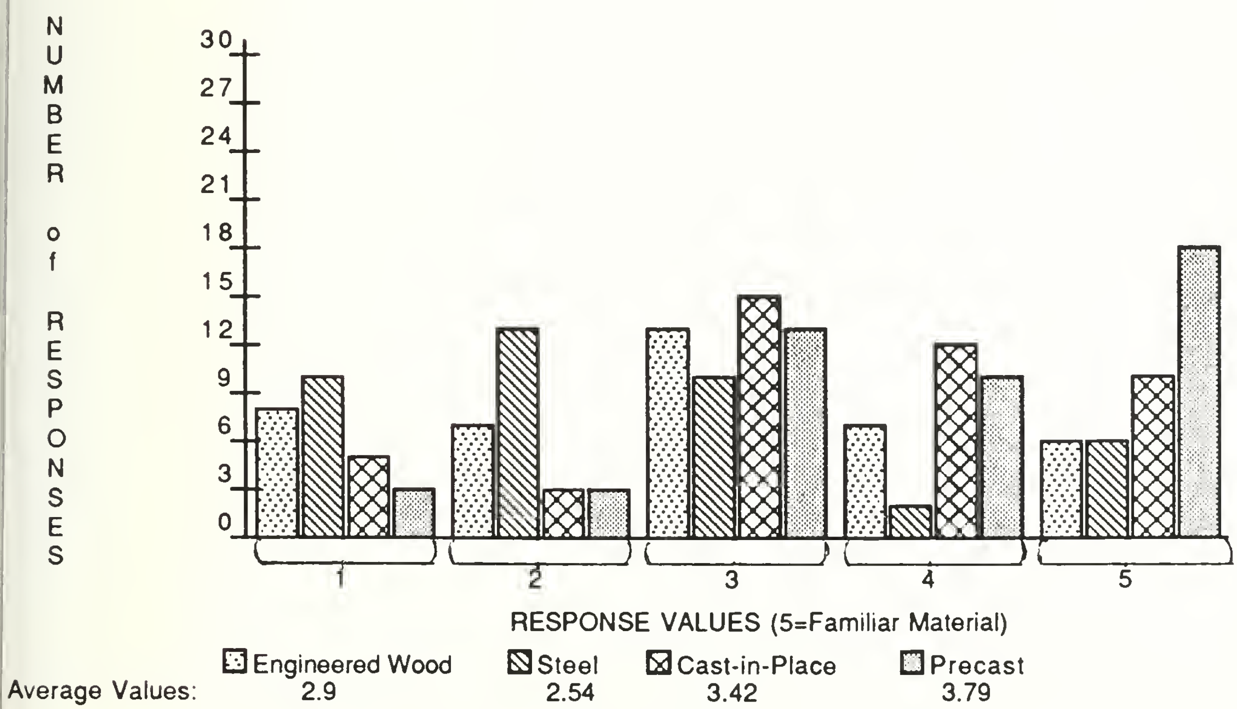


Figure 13.
Familiarity of the Materials in the Departments

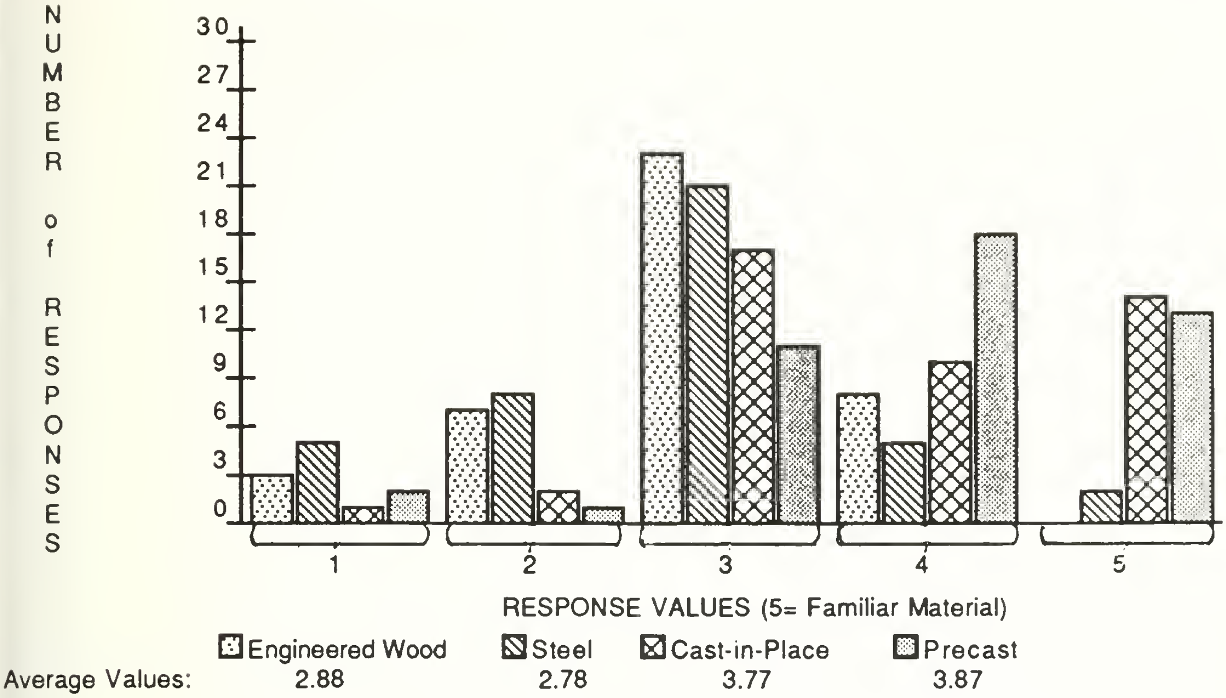


Figure 14.
Familiarity of Contractors with the Materials

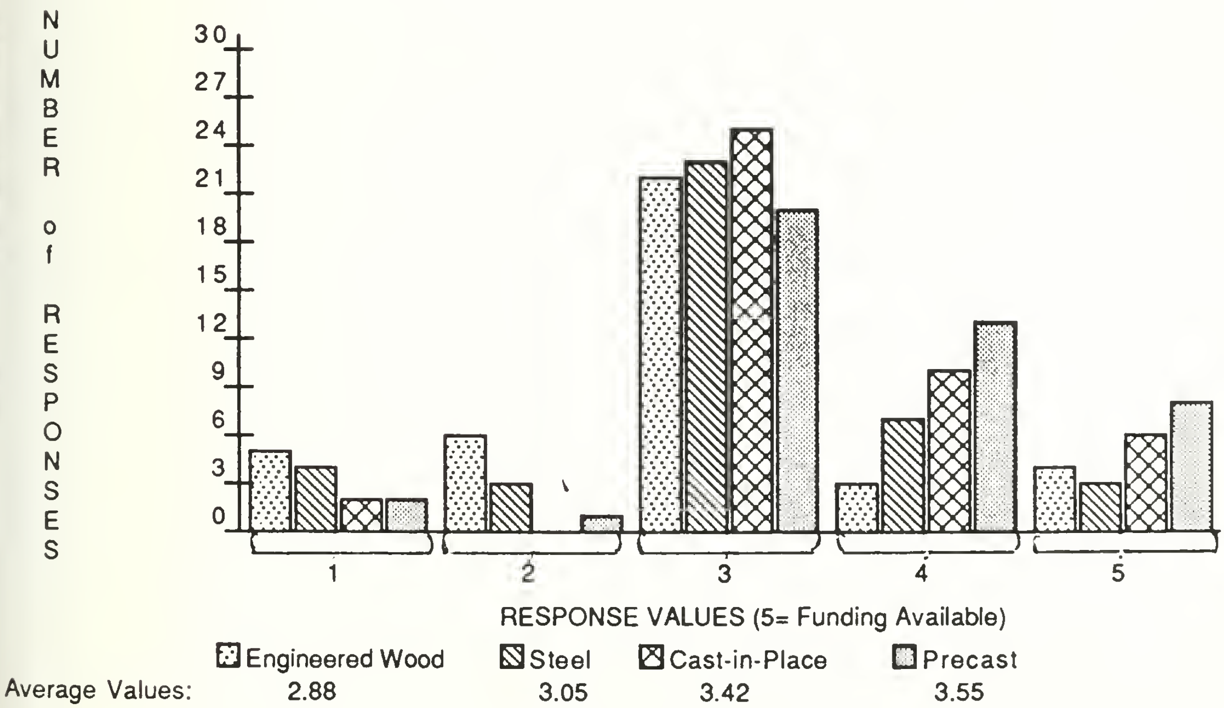


Figure 15.
Comparison of the Availability of Funding

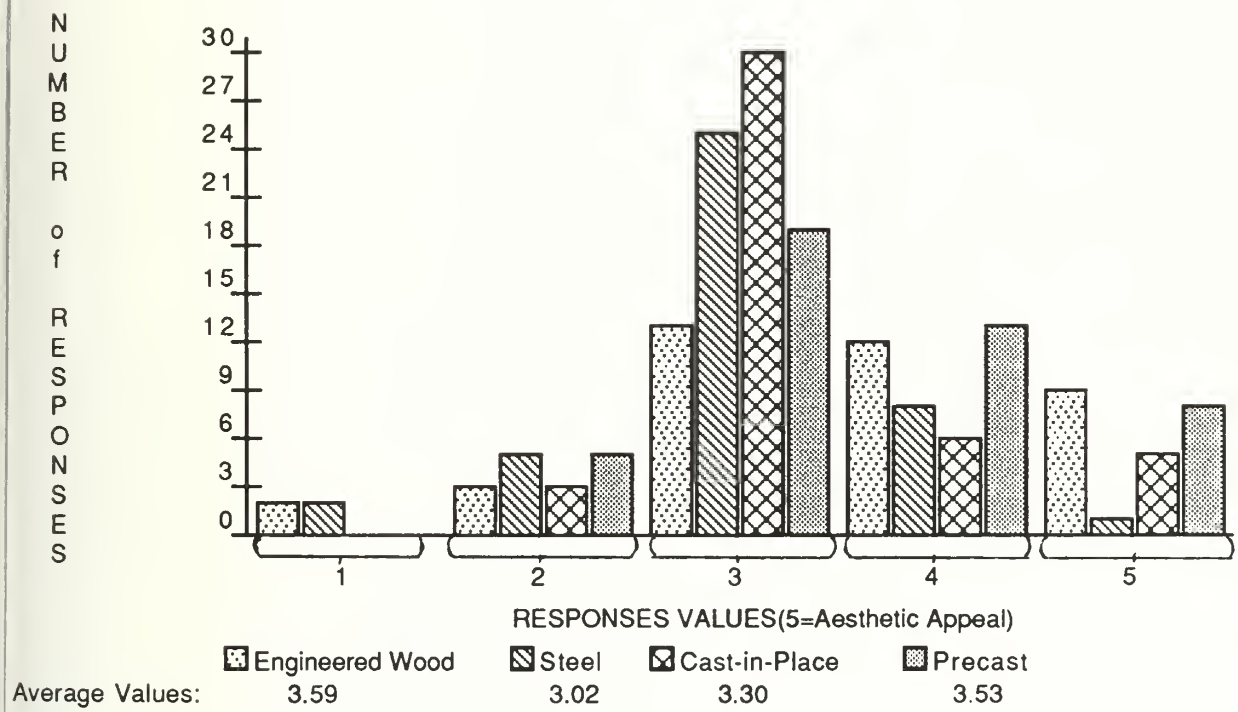


Figure 16.
Relative Aesthetic Value of the Materials

Table 8. Average Responses for Substructure andSuperstructure Material Selection Factors (1=least important,10=most important)

FACTOR	IMPORTANCE in SUBSTRUCTURE MATERIAL SELECTION	IMPORTANCE in SUPERSTUCTURE MATERIAL SELECTION
Maintenance Costs	8.43	8.57
Durability	8.44	8.26
Construction Costs	8.08	8.07
Total Life Cycle Costs	7.95	8.07
Material Costs	7.58	7.45
Material Availability	7.24	7.28
Speed of Construction	6.80	7.07
Familiarity of Design	6.18	6.32
Funding Requirements	6.18	6.00
Environmental Impact	5.74	5.49
Aesthetics	4.30	4.55

as the number of material suppliers, was not as readily available and were not answered with the same frequency or degree of confidence. However all the responses proved valuable in determining which materials are being utilized in short span bridges and what factors influence material selection.

Summary

Rarely does a county public works director assign an engineering staff full time to the county bridge program. Time constraints and other responsibilities may limit county engineers from exploring multiple bridge replacement options, choosing instead an expedient "standard design" commonly utilized in the county.

Federal funding of county bridge projects was anticipated since the HBRRP authorizes the FHWA to fund up to 80 % of projects on the national bridge inventory. This may result in many counties deferring bridge work until federal funds become available, allocating limited county resources to other equally or less pressing requirements. In Washington, Oregon, and Idaho; state funding typically is not allocated to bridges off the Federal-aid system.

County officials are responsible for funding the maintenance of the bridges under county jurisdiction. Limited maintenance budgets influence county bridge designs and material selection. County engineers are encouraged to choose materials that require low maintenance despite high initial costs because the federal government will fund up to 80% of a bridge project. These low maintenance costs reduce the total annual county maintenance expenditures. In some locations bridge materials with high initial costs and low maintenance requirements may not be the most economical in terms of overall life cycle costs. However, such materials are attractive to county officials because a larger portion of the total life cycle costs are funded by the federal government "up front" thereby reducing county expenditures.

There are twice as many existing wooden bridges requiring replacement than either concrete or steel. This may be due to the total number of existing wooden bridges being greater than the total number of existing concrete or steel bridges. It is also possible that the majority of existing wooden bridges are older than existing concrete and steel bridges. Wooden bridges may not be as durable for the majority of site conditions encountered. Most respondents indicated that wood is not as durable as steel, cast-in-place concrete, or precast concrete and has the highest maintenance costs of all three materials. Inadequate maintenance would have the most significant impact on wooden bridges resulting in deterioration and earlier replacement. Limited county budgets may have restricted the minimum levels of required maintenance.

Most bridge costs are established from the final price of construction contracts. However each bridge site is unique with many variables that effect design and make it difficult at best to compare costs between materials. Bridge costs are influenced by: site conditions, time of construction, design, material costs, and competition. Material cost is only one of many factors that determine the overall cost of a bridge project. The costs provided by the county officials (see Appendix E) reflect this variability. The true indication of the economics of the different materials can only be determined by considering each bridge site individually and performing an economic analysis on each site for each material.

Bridge selection is significantly influenced by economics. This is readily apparent from the priority and weight given to factors in Table 7. County officials gave greater emphasis to long term

expenditures such as maintenance and durability rather than short term expenditures such as construction or material costs.

Upon completion, a bridge funded under the Highway Bridge Replacement and Rehabilitation Program (HBRRP) must comply with all HBRRP standards and regulations and be free of deficiencies. Unlike concrete and steel wooden guard rails do not meet the criteria of the HBRRP. The HBRRP follows the AASHTO codes as do the majority of counties. Wooden guard rails do not meet the crash test criteria of AASHTO and therefore do not meet the requirements of the HBRRP. Since federal funding under the HBRRP is not available for wooden bridges they will not often be considered.

Conclusions

Concrete is the material of choice for most short span bridges. Durability and low maintenance are the two key factors delineating its superiority over steel and wood. Most substructures are cast-in-place concrete while superstructures show a high utilization of precast elements. For decking there is a slightly higher preference for precast deck panels. In the future, four out of five new superstructures will be built of precast concrete elements. The large majority of bridges will be built by contractors and not county crews.

Precast concrete was considered the material with the greatest number of advantages for utilization in short span bridge superstructures and decking. Superior quality control of the finished concrete along with faster construction has contributed to its dominance over cast-in-place concrete. In forty years it has become the dominant material for short span bridge construction and will show increasing use in the future.

Cast-in-place concrete was the material with the second greatest number of advantages. The noted disadvantages of cast-in-place concrete are related to construction. Construction is slower and construction costs are considerbly higher than precast concrete for superstructures and bridge decking. However it is easier and more cost effective to form and place concrete substructures than it is to assemble precast elements. Cast-in-place concrete does not require heavy lifting equipment which reduces the placing cost in comparison to precast elements. This accounts for the predominant use of cast-in-place concrete for bridge abutments, footings, and retaining walls.

Engineered wooden bridges have many positive factors that warrant consideration. Wooden bridges have simple designs, low construction costs, and can be constructed in a relatively short time. The initial costs for engineered wood superstructures may be economically competitive with precast concrete elements and more economical than cast-in-place concrete or steel superstructures. A number of counties use wood for superstructures and decking in low volume spans under 30 ft. There is a potential for greater utilization of engineered wood bridges considering the majority of low volume bridges that exist and the fact that approximately one third of the county bridges requiring replacement are under 30 ft.

Despite these observations, wood will rarely be utilized in substructures and superstructures. Other factors outweigh the low initial cost for wooden bridges. The maintenance required on wooden bridges and their poor durability discourages greater utilization. Although wooden bridges can be assembled with semi-skilled labor, such as county crews, the majority of county bridges are built by contract instead of by county personnel.

Wood preservers claim that wooden bridges can be expected to last 50 years with contemporary preservation methods. However the general consensus of county officials is that wooden bridges are still subject to decay. This conception needs to be dispelled before wooden bridges will be considered a viable choice for short span bridges.

Steel is generally not considered by county officials for substructures or superstructures of short span bridges, due to high initial costs as well as painting requirements. The initial cost of

construction and long term expenditures are higher than concrete. The small number of counties that do utilize steel structures consider them only for spans between 30 and 60 feet.

Twenty two years after the Silver Bridge collapse in West Virginia, county officials in the Northwest are very sensitive to the importance and cost of bridge maintenance. Low maintenance and high durability are the two principle factors that influence the selection of bridge materials. Materials that have these characteristics such as precast concrete and cast-in-place concrete are typically chosen by county officials, even for bridges with low traffic volumes. However, in isolated areas wooden or steel bridges are still preferred over precast or cast-in-place structures because of low initial costs and ease of erection. These counties are aware, as recommended by Sprinkel, (1985) , that it is more economical to reduce first costs rather than long term maintenance costs for low volume bridges. The higher initial cost of a more durable and easier to maintain bridge may never be recovered in the service life of the structure.

Maintenance costs are funded completely by the counties, however; the federal government will pay, through the Highway Bridge Replacement and Rehabilitation Program, up to 80% of the cost of a new bridge or rehabilitation of an old bridge. This funding structure influences county officials to choose materials that have low maintenance cost even if the initial costs are higher in comparison to other materials. The federal government will pay a large portion of the "up front" costs and county expenditures on maintenance will be reduced over the life of the bridge. More of the

total life cycle costs of the structure are paid "up front" by the federal government in lieu of over the life of the bridge by the county.

The bridge infrastructure in Idaho, Oregon, and,Washington still requires extensive rehabilitation and replacement. However federal programs are in place that provide funding for county bridge projects both on and off the Federal aid system. The HBRRP will assist counties in funding bridge rehabilitation and replacement but additional funding is necessary if all existing and future deficient bridges are to be corrected.

Recommendations

Funding sources for bridge rehabilitation and replacement will become exceedingly limited with legislated reductions in the federal budget. County officials may be forced to make bridge selections that have lower initial costs. Shifting economic conditions may have a marked influence on the initial cost of materials. In particular, rising energy costs will impact the cost of construction materials in varying degrees. County officials should be aware of the ripple effect that rising energy costs have on total life cycle costs for precast concrete, cast-in-place concrete, steel, and wooden bridges. Economic analyses should be performed with designs of concrete, steel, and wood to determine if reduced expenditures on maintenance justify higher initial construction costs.

Concrete clearly has many advantages over steel and wood for short span bridges; however, it is still the material with the heaviest dead load. Bridges that utilize existing substructures typically are more economical. Due to the heavier dead load, concrete may not be

used on substructures which were constructed for steel or wooden superstructures. County officials may need to work closely with concrete producers to determine if a economical lightweight concrete is available to utilize existing substructures.

County officials receive a large portion of rehabilitation and replacement funding under the HBRRP. Bridges funded under this program must comply with AASHTO criteria. Since wooden guard rails have not been crash tested in accordance with the AASHTO criteria they are not eligible for federal funding. Wooden bridge fabricators should have a standard rail design tested and accepted in accordance with the AASHTO criteria. This would make it possible for counties to seek funding for wooden bridges under the HBRRP.

Steel maintenance and fabrication costs must be reduced if steel is to become a practical short span material. Steel producers should concentrate on developing a true weathering steel for the climates encountered in the Pacific Northwest. This would eliminate the painting requirement and would make steel a more economical choice for the county engineers.

Further Research

Twice as many wooden bridges require replacement as concrete or steel bridges. This would appear to validate the consensus of county officials who do not believe wood is a durable bridge material. Further investigation is warranted to determine the reason more wooden bridges are in need of replacement than steel or concrete.

County officials felt that steel and wooden bridges were not as economical as concrete bridges. However few if any counties actually

keep records of complete life cycle costs. It would be beneficial to conduct further research into life cycle costs. Case studies could be performed on wooden steel and concrete bridges under similar conditions. All costs associated with these bridges could be reconstructed to determine estimated life cycle costs. This would provide further insight into which materials are the most economical.

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Appendix A Cover Letter and Survey

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

ent of Civil Engineering

eptember 4, 1990

)ear Sir,

Ve at the University of Washington (Graduate Program of Construction Engineering and Management) are conducting a study of short span (less than 120 feet) bridges in counties in daho, Oregon, and Washington. The attached survey is focused on materials used in construction of new short spans. The questions focus on the use of cast in place (CIP) concrete, precast concrete, steel, and wood. The purpose of the study is to determine the role that various factors play in the selection of short span bridge materials.

This survey has been formulated so that it will take an individual familiar with the county bridge program approximately 15-20 minutes to complete. Your participation in the survey is important for the success of this study. It is important that the survey be returned even if some questions cannot be answered. It will be most helpful if the survey is returned by October 1, 1990.

In appreciation of your participation in this study a summary report of this research will be provided. This report will provide you with information on how other counties are addressing the replacent of their short span bridges. Your individual responses will be kept confidential.

We would personally like to thank you for taking the time to complete the enclosed survey.

SHORT SPAN BRIDGE SURVEY of IDAHO, OREGON and WASHINGTON COUNTIES

INFORMATION ABOUT COUNTY BRIDGE PROGRAM

County Name:______________ State:___________

1) Does the County Public Works Department have a full time bridge engineering staff?_________

2) Number of county engineers assigned full time to bridge program? _________

3) Typically how much is spent annually for bridge: Repair? $____________
Replacement? $____________

4) By percentage what have been the sources of funding for replacement?: ___________% County
___________% State
___________% Federal

5) What code or codes are used to design new bridges?
(AASHTO, State, Other):____

INFORMATION ABOUT COUNTY BRIDGES

6) How many BRIDGES are under your county jurisdiction? ______________

7) How many bridges have AVERAGE DAILY TRAFFIC less than 400 vehicles per day __________
400 - 2000 vehicles per day __________
more than 2000 vehicles per day __________

8) How many BRIDGES, which are predominately of the following materials, require REPLACEMENT?
Concrete--->__________ bridges
Steel------>__________ bridges
Wood------>__________ bridges

9) What are the LENGTHS of the bridges requiring REPLACEMENT?
Less than 30 feet__________ bridges or ______%
30-60 feet----> __________ bridges or ______%
60-120 feet---> __________ bridges or ______%

10) How many new bridges will be made predominately of the following materials?
Cast in Place Concrete__________ bridges or ______%
Pre-cast Concrete--> __________ bridges or ______%
Steel-------------> __________ bridges or ______%
Wood-------------> __________ bridges or ______%

11) What percentage of new bridges are typically built by the following sources?

	Contractor	County Crews	Other (________________)
Cast in Place Concrete	__________ %	____________%	____________%
Pre-cast Concrete-->	__________ %	____________%	____________%
Steel------------->	__________ %	____________%	____________%
Wood------------->	__________ %	____________%	____________%

12) How many new bridges were built or are under construction during 1988-1990 and what are their lengths?___________ total

	Less than 30 feet	30-60 feet	60-120 feet
Cast in Place Concrete	_________ bridges	_________ bridges	__________ bridges
Pre-cast Concrete-->	_________ bridges	_________ bridges	__________ bridges
Steel-------------->	_________ bridges	_________ bridges	__________ bridges
Wood-------------->	_________ bridges	_________ bridges	__________ bridges

13) What was the AVERAGE COST of new bridges (in $ PER FT of deck surface) for the following materials?

	1988	1989	1990
Cast in Place Concrete	$________	$________	$________
Pre-cast Concrete-->	$________	$________	$________
Steel------------->	$________	$________	$________
Wood------------->	$________	$________	$________

COMMENTS:____

____

14) Please indicate the number of suppliers of the following bridge materials and proximity to the county?

	< 10 miles	10 - 100 miles	100 - 200 miles
Cast in Place Concrete	________	________	________
Pre-cast Concrete-->	________	________	________
Steel------------->	________	________	________
Wood------------->	________	________	________

15) WEIGHT, [FROM 1 (Low Utilization) THROUGH 10 (High Utilization], the USE of the following materials in the components of new bridges:

	Substructure	Superstructure	Decking
Cast in Place Concrete	________	________	________
Pre-cast Concrete-->	________	________	________
Steel------------->	________	________	________
Wood------------->	________	________	________

16) Rate the advantages of Cast In Place Concrete as a bridge material?

	Disadvantage		Neutral		Advantage
Simple Design	1	2	3	4	5
Familiarity in Department	1	2	3	4	5
Material Cost	1	2	3	4	5
Material Availability	1	2	3	4	5
Initial Construction Cost	1	2	3	4	5
Contractor's Familiarity	1	2	3	4	5
Speed of Construction	1	2	3	4	5
Low Maintenance	1	2	3	4	5
Durability	1	2	3	4	5
Funding Available (State/Fed)	1	2	3	4	5
Aesthetics	1	2	3	4	5
Other( )	1	2	3	4	5

COMMENTS:____

____

17) Rate the advantages of Pre-Cast/ Prefabricated Concrete as a bridge material?

	Disadvantage		Neutral		Advantage
Simple Design	1	2	3	4	5
Familiarity in Department	1	2	3	4	5
Material Cost	1	2	3	4	5
Material Availability	1	2	3	4	5
Construction Cost	1	2	3	4	5
Contractor's Familiarity	1	2	3	4	5
Speed of Construction	1	2	3	4	5
Low Maintenance	1	2	3	4	5
Durability	1	2	3	4	5
Funding Available (State/Fed)	1	2	3	4	5
Aesthetics	1	2	3	4	5
Other( )	1	2	3	4	5

COMMENTS:____

____

18) Rate the advantages of Steel as a bridge material?

	Disadvantage		Neutral		Advantage
Simple Design	1	2	3	4	5
Familiarity in Department	1	2	3	4	5
Material Cost	1	2	3	4	5
Material Availability	1	2	3	4	5
Construction Cost	1	2	3	4	5
Contractor's Familiarity	1	2	3	4	5
Speed of Construction	1	2	3	4	5
Low Maintenance	1	2	3	4	5
Durability	1	2	3	4	5
Funding Available (State/Fed)	1	2	3	4	5
Aesthetics	1	2	3	4	5
Other( )	1	2	3	4	5

COMMENTS:____

____

19) Rate the advantages of Engineered Wood as a bridge material?

	Disadvantage		Neutral		Advantage
Simple Design	1	2	3	4	5
Familiarity in Department	1	2	3	4	5
Material Cost	1	2	3	4	5
Material Availability	1	2	3	4	5
Construction Cost	1	2	3	4	5
Contractor's Familiarity	1	2	3	4	5
Speed of Construction	1	2	3	4	5
Low Maintenance	1	2	3	4	5
Durability	1	2	3	4	5
Funding Available (State/Fed)	1	2	3	4	5
Aesthetics	1	2	3	4	5
Other( )	1	2	3	4	5

COMMENTS:____

____

20) WEIGHT, [FROM 1 (LEAST important) THROUGH 10 (MOST important], the RELATIVE IMPORTANCE of the following factors in the selection of new bridge MATERIAL:

	for SUPERSTRUCTURE:	for SUBSTRUCTURE:
-FAMILIARITY OF DESIGN	___	___
-MATERIAL COSTS	___	___
-MATERIAL AVAILABILITY	___	___
-CONSTRUCTION COSTS	___	___
-SPEED OF CONSTRUCTION	___	___
-MAINTENANCE COSTS	___	___
-DURABILITY	___	___
-TOTAL LIFE CYCLE COSTS	___	___
-REQUIRED BY STATE/FEDERAL FUNDING SOURCE	___	___
-AESTHETICS	___	___
-ENVIRONMENTAL IMPACT	___	___
-OTHER (____________________)	___	___

If you would like a copy of the summary report, please provide the following information:

(ALL OF YOUR RESPONSES WILL REMAIN CONFIDENTIAL)

Name----->____________________________ Title______________________

Address--->_________________________ Telephone->(____) -____ -________

--->____________________________

--->__________________________ Zip_____________

Appendix B Summary of Responses

1) Does the county have a full time bridge	N	N	N	N		
engineering staff?						
2) Number of engineers on bridge staff?	0	0	0.1	0	0	1
3) Typically how much is spent annually :						
for bridge repair?	$15000.00	$14000.00	$35000.00	$50000.00	$0.00	
for bridge replacement?	$75000.00	$100000.00	$200000.00	$500000.00	$200000.00	
4) What have been the sources of funding						
for replacement?						
%County	50	20	20	25	40	25
% State	30	0	0	0	0	
% Federal	20	80	80	75	60	75
5) What code(s) are used to design new	AASHTO	State	AASHTO	AASHTO	AASHTO	AASHTO
bridges? (AASHTO, State, Other)						
6) How many bridges in your jurisdiction?	138	15	56	42	41	69
7)How many bridges have						
AVERAGE DAILY TRAFFIC:						
ADT < 400	132	13	30	25	15	28
400 - 2000	6	1	20	14	25	29
> 2000	0	1	6	3	1	12
8) How many bridges require replacement?						
Concrete	5	1	1	2	1	2
Steel	5	3	1	4	3	1
Wood	15	0	6	0	2	2
9) Lengths requiring replacement:						
Less 30 ft.	4	1	50.00%	0	0	
30-60 ft.	3	3	40.00%	4	2	3
60-120 ft.	13		10.00%	2	2	2
10) How many new bridges will be made of						
the following materials? (number or %)						
Cast in Place	0		0.00%	0	0.00%	
Pre Cast Concrete	25	2	100.00%	6	75.00%	5
Steel	0		0.00%	0	0.00%	
Wood	0	2	0.00%	0	25.00%	

1) Does the county have a full time bridge	N	N	N			
engineering staff?						
2) Number of engineers on bridge staff?	0	0	0	3/50%	0	0
3) Typically how much is spent annually :						
for bridge repair?	$20000.00	$50000.00	$3000.00	$30000.00		$10000.00
for bridge replacement?	$100000.00	$200000 00	$75000.00	$600000.00		$565000.00
4) What have been the sources of funding						
for replacement?						
%County	20	50	20	25		20
% State	0	0	0	0		0
% Federal	80	50	80	75		80
5) What code(s) are used to design new	AASHTO	AASHTO/STATE	State	AASHTO/WSDOT	AASHTO	FHWA
bridges? (AASHTO, State, Other)						
6) How many bridges in your jurisdiction?	65	60	14	152	56	24
7)How many bridges have						
AVERAGE DAILY TRAFFIC:						
ADT < 400	65	44	10	100	33	10
400 - 2000	0	8	4	42	20	11
> 2000	0	8	0	10	3	3
8) How many bridges require replacement?						
Concrete	1	0	1	2	0	
Steel	0	0	2	5	2	
Wood	12	1		10	7	
9) Lengths requiring replacement:						
Less 30 ft.	0			4	1	
30-60 ft.	13			5	3	
60-120 ft.	0	1	3	8	5	
10) How many new bridges will be made of						
the following materials? (number or %)						
Cast in Place	0			0		
Pre Cast Concrete	13		3	17	9	
Steel	0	Culvert		0		
Wood	0			0		

1) Does the county have a full time bridge engineering staff?	Y	NO	N	N	[illegible]	
2) Number of engineers on bridge staff?	1	0	0	0	1	2/Part time
3) Typically how much is spent annually :						
for bridge repair?	N/A	$10000.00	$45000.00	$5000.00		
for bridge replacement?	N/A	$100000.00	$275000.00	$150000.00	$200000.00	
4) What have been the sources of funding for replacement?						
%County	50		25	20	50	20
% State			0	0		
% Federal	50		75	80	50	80
5) What code(s) are used to design new bridges? (AASHTO, State, Other)	AASHTO	AASHTO- WSDOT		AASHTO	AASHTO	AASHTO
6) How many bridges in your jurisdiction?	195	25	220	63	213	135
7)How many bridges have AVERAGE DAILY TRAFFIC:						
ADT < 400			100	63	134	134
400 - 2000			110	0	70	1
> 2000			10	0	9	
8) How many bridges require replacement?						
Concrete	2	20		0	3	5
Steel	10			10	7	16
Wood	3	5		0	3	4
9) Lengths requiring replacement:						
Less 30 ft.	4	1			3	6
30-60 ft.	5	4			3	15
60-120 ft.	6			10	7	4
10) How many new bridges will be made of the following materials? (number or %)						
Cast in Place	30.00%		10.00%	5		
Pre Cast Concrete	60.00%	100.00%	80.00%	5	13	25
Steel	9.00%		10.00%			
Wood	1.00%		0.00%			

1) Does the county have a full time bridge engineering staff?	No	No	Yes	No	No	[illegible]
2) Number of engineers on bridge staff?		0	2	0	0	3 Eng/ 9 others
3) Typically how much is spent annually:						
for bridge repair?	$20000.00	$3000.00		$1000.00	$140000.00	$650000.00
for bridge replacement?	$300000.00			$0.00	$40000.00	$1-3 Million
4) What have been the sources of funding for replacement?						
%County	20	50	20	0	20	20
% State		50		0		0
% Federal	80		80	0	80	80
5) What code(s) are used to design new bridges? (AASHTO, State, Other)	AASHTO	State	AASHTO	State	AASHTO	AASHTO,State,
6) How many bridges in your jurisdiction?	63	13	126	3	91	190
7)How many bridges have AVERAGE DAILY TRAFFIC:						
ADT < 400	61	13	53	1	41	
400 - 2000	2		41	1	40	
> 2000			32	1	10	
8) How many bridges require replacement?						
Concrete		0	2	2	2	4
Steel	3	0	4		0	8
Wood	16	0	4		3	27
9) Lengths requiring replacement:						
Less 30 ft.	3	0	0	2	2	10.00%
30-60 ft.	4	0	2		2	10.00%
60-120 ft.	12	0	0		1	30.00%
10) How many new bridges will be made of the following materials? (number or %)						
Cast in Place	7	0	1.00%			5.00%
Pre Cast Concrete	12	0	89.00%		5	95.00%
Steel		0	10.00%			
Wood		0		2		

1) Does the county have a full time bridge	No	No	No	No		
engineering staff?						
2) Number of engineers on bridge staff?	0	50.00%	0	0		0
3) Typically how much is spent annually :						
for bridge repair?	$225000.00	$50000.00	$0.00	$60000.00	$15000.00	$354000.00
for bridge replacement?	$550000.00	$700000.00	$0.00	$80000.00	$200000.00	$1500000.00
4) What have been the sources of funding						
for replacement?						
%County	20	10	20	100	40	75
% State		90			10	5
% Federal	80	80	80		50	20
5) What code(s) are used to design new	AASHTO & Stat	AASHTO & Stat	State	AASHTO	AASHTO	AASHTO
bridges? (AASHTO, State, Other)						
6) How many bridges in your jurisdiction?	102	320	86	112	70	300
7)How many bridges have						
AVERAGE DAILY TRAFFIC:						
ADT < 400	30	300	86	78	50	180
400 - 2000	48	20		22	18	163
> 2000	24			12	2	27
8) How many bridges require replacement?						
Concrete	60	20	0	0	2	1
Steel	24	10	2	1	0	6
Wood	18	50	4	7	15	24
9) Lengths requiring replacement:						
Less 30 ft.	3	40		1	3	9
30-60 ft.	1	20	5	4	10	11
60-120 ft.	7	20		3	2	6
10) How many new bridges will be made of						
the following materials? (number or %)						
Cast in Place	3	0	0.00%	0.00%		0
Pre Cast Concrete	8	75	100.00%	30.00%	100.00%	31
Steel		0	0.00%	10.00%		0
Wood		5	0.00%	10.00%		0

1) Does the county have a full time bridge engineering staff?	No	No	No	No		
2) Number of engineers on bridge staff?	0	0	0	0	5	0.1
3) Typically how much is spent annually :						
for bridge repair?	$2000.00	$50000.00	$5000.00	$15000.00	$1500000.00	
for bridge replacement?	$0.00	$0.00	$30000.00	$60000.00	$0.00	
4) What have been the sources of funding for replacement?						
%County	10	25	6	10	10	
% State	20	25	6	10	10	
% Federal	70	50	80	80	80	
5) What code(s) are used to design new bridges? (AASHTO, State, Other)		State	AASHTO	AASHTO	AASHTO	AASHTO
6) How many bridges in your jurisdiction?	18	39	18	165	42	140
7)How many bridges have AVERAGE DAILY TRAFFIC:						
ADT < 400	18	39	12	145	5	
400 - 2000			6	18	8	
> 2000				2	29	5
8) How many bridges require replacement?						
Concrete	13	1	0	0	0	0
Steel	3		0	1	1	0
Wood	2		1	2	1	35
9) Lengths requiring replacement :						
Less 30 ft.			1			60.00%
30-60 ft.			0		1	20.00%
60-120 ft.	100.00%	1	0			20.00%
10) How many new bridges will be made of the following materials? (number or %)						
Cast in Place				1	50.00%	0.00%
Pre Cast Concrete	100.00%	1		3	50.00%	90.00%
Steel				0		5.00%
Wood				0		5.00%

1) Does the county have a full time bridge engineering staff?	No					
2) Number of engineers on bridge staff?	0	0	0	0	0.1	0
3) Typically how much is spent annually:						
for bridge repair?	$100000.00	$30000.00	$40000.00		$50000.00	$200000.00
for bridge replacement?	$450000.00	$100000.00	$0.00		$75000.00	$600000.00
4) What have been the sources of funding for replacement?						
%County	94	90	100		10	8
% State	8	5	0		10	12
% Federal	8	5	0		80	80
5) What code(s) are used to design new bridges? (AASHTO, State, Other)	AASHTO & OSH	AASHTO/State	State		State	State
6) How many bridges in your jurisdiction?	91	350	89	52	80	134
7)How many bridges have AVERAGE DAILY TRAFFIC:						
ADT < 400	58	332	60	52	60	97
400 - 2000	32	145	24	52	19	35
> 2000	1	4	5	0	1	2
8) How many bridges require replacement?						
Concrete	0	0	1	0	0	
Steel	5	1	1	8	0	
Wood	12	25	40	4	10	2
9) Lengths requiring replacement:						
Less 30 ft.	3	68	25	0	6	2
30-60 ft.	6	10	8	0	3	
60-120 ft.	3	6	9	12	1	
10) How many new bridges will be made of the following materials? (number or %)						
Cast in Place					1	
Pre Cast Concrete	27				9	2
Steel		50.00%				
Wood		50.00%				

1) Does the county have a full time bridge engineering staff?	No	No				
2) Number of engineers on bridge staff?	0		0	0	0	0
3) Typically how much is spent annually:						
for bridge repair?	$5000.00		$15000.00	$75000.00	$40000.00	$12000.00
for bridge replacement?	$3000.00		$35000.00	$60000.00	$0.00	
4) What have been the sources of funding for replacement?						
%County			10	100	50	20
% State	100		15		50	80
% Federal			75		0	
5) What code(s) are used to design new bridges? (AASHTO, State, Other)	AASHTO		AASHTO	STATE	AASHTO	AASHTO
6) How many bridges in your jurisdiction?	41	42	100	18	35	71
7)How many bridges have AVERAGE DAILY TRAFFIC:						
ADT < 400	27	40	65	13	15	61
400 - 2000	14	2	25	5	20	10
> 2000			10	0		
8) How many bridges require replacement?						
Concrete			25	4	4	0
Steel	1		5	4	15	1
Wood	5	5	5	12	1	2
9) Lengths requiring replacement:						
Less 30 ft.		2	23	3	0	2
30-60 ft.	4	2	9	2	5	
60-120 ft.	2	1	5	1	15	1
10) How many new bridges will be made of the following materials? (number or %)						
Cast in Place		1	70.00%		0	
Pre Cast Concrete	6	4	30.00%	1	5	1
Steel					15	
Wood				5		2

11) What percentage of new bridges are typically built by the following sources?						
Contractor:						
Cast in Place	0.00%	100.00%	0.00%			
Pre Cast Concrete	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Steel	0.00%	100.00%	0.00%		100.00%	
Wood	0.00%	100.00%	0.00%		100.00%	
County Crews						
Cast in Place	0		0.00%		0	
Pre Cast Concrete	0		0.00%		0	
Steel	0		0.00%		0	
Wood	0		0.00%		0	
12) How many new bridges were built or are under construction during 1988-90 and what are their lengths?						
Total:	6	0	5	3	2	1
Less 30 ft.						
Cast in Place						
Pre Cast Concrete			4			
Steel						
Wood						
30-60 ft.						
Cast in Place						
Pre Cast Concrete	5		1	1		
Steel						
Wood						
60-120 ft.						
Cast in Place						1
Pre Cast Concrete	1			2		
Steel						
Wood						

11) What percentage of new bridges are typically built by the following sources?						
Contractor:						
Cast in Place		100.00%		100.00%	100.00%	100.00%
Pre Cast Concrete	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Steel		100.00%		100.00%	100.00%	100.00%
Wood		100.00%		100.00%	90.00%	0.00%
County Crews						
Cast in Place						
Pre Cast Concrete						
Steel						
Wood					10.00%	
12) How many new bridges were built or are under construction during 1988-90 and what are their lengths?						
Total:	2	0	2	4		101
Less 30 ft.						
Cast in Place						
Pre Cast Concrete						
Steel						
Wood			1			
30-60 ft.						
Cast in Place						
Pre Cast Concrete	1				1	1
Steel						
Wood				1		
60-120 ft.						
Cast in Place						
Pre Cast Concrete	1		1	3		1
Steel						
Wood						

11) What percentage of new bridges are						
typically built by the following sources?						
Contractor:				100.00%		
Cast in Place	100.00%			100.00%	100.00%	
Pre Cast Concrete	100.00%	100.00%	30.00%		100.00%	65.00%
Steel	100.00%		5.00%			
Wood	75.00%					
County Crews						
Cast in Place						
Pre Cast Concrete			10.00%			35.00%
Steel						
Wood	25.00%		50.00%			
12) How many new bridges were built or						
are under construction during 1988-90 and						
what are their lengths?						
Total:	1	0	170	1		2
Less 30 ft.						
Cast in Place						
Pre Cast Concrete						
Steel						
Wood						
30-60 ft.						
Cast in Place					3	
Pre Cast Concrete						1
Steel						
Wood						
60-120 ft.						
Cast in Place						
Pre Cast Concrete			2	1		1
Steel	1					
Wood						

11) What percentage of new bridges are typically built by the following sources?						
Contractor:						
Cast in Place	100.00%	100.00%	100.00%		100.00%	100.00%
Pre Cast Concrete	100.00%		100.00%		100.00%	100.00%
Steel		100.00%	100.00%		100.00%	100.00%
Wood			100.00%	100.00%	100.00%	
County Crews						
Cast in Place						
Pre Cast Concrete		100.00%				
Steel						
Wood		100.00%				100.00%
12) How many new bridges were built or are under construction during 1988-90 and what are their lengths?						
Total:	8	0	2	0	0	9
Less 30 ft.						
Cast in Place	1					
Pre Cast Concrete						
Steel						
Wood						
30-60 ft.						
Cast in Place						
Pre Cast Concrete	1					
Steel						
Wood						
60-120 ft.						
Cast in Place						
Pre Cast Concrete	5		1			9
Steel						
Wood	1					

11) What percentage of new bridges are typically built by the following sources?						
Contractor:						
Cast in Place	100.00%			100.00%		0.00%
Pre Cast Concrete	100.00%	75.00%	99.00%	100.00%	100.00%	70.00%
Steel				100.00%		0.00%
Wood				50.00%		0.00%
County Crews						
Cast in Place						
Pre Cast Concrete		25.00%				20.00%
Steel			1.00%			10.00%
Wood		100.00%		50.00%		
12) How many new bridges were built or are under construction during 1988-90 and what are their lengths?						
Total:		16		2	6	3
Less 30 ft.						
Cast in Place						
Pre Cast Concrete		2				1
Steel						
Wood		8		1		
30-60 ft.						
Cast in Place						
Pre Cast Concrete			1			
Steel						2
Wood				1		
60-120 ft.						
Cast in Place	3					
Pre Cast Concrete		6			6	
Steel						
Wood						

11) What percentage of new bridges are typically built by the following sources?						
Contractor:						
Cast in Place			1		100.00%	1
Pre Cast Concrete	100.00%	10.00%	1		100.00%	1
Steel			0		100.00%	
Wood					100.00%	
County Crews						
Cast in Place						
Pre Cast Concrete						
Steel						
Wood			1			
12) How many new bridges were built or are under construction during 1988-90 and what are their lengths?						
Total:	0	0	0	4	0	2
Less 30 ft.						
Cast in Place				1		
Pre Cast Concrete				2		
Steel				0		
Wood				0		
30-60 ft.						
Cast in Place				0		
Pre Cast Concrete				1		2
Steel				0		
Wood				0		
60-120 ft.						
Cast in Place						
Pre Cast Concrete						
Steel						
Wood						

11) What percentage of new bridges are typically built by the following sources?						
Contractor:						
Cast in Place		100.00%	100.00%	4.00%	100.00%	
Pre Cast Concrete	100.00%	100.00%	100.00%	95.00%	40.00%	100.00%
Steel			100.00%	1.00%		
Wood			100.00%			
County Crews						
Cast in Place						
Pre Cast Concrete					60.00%	
Steel		100.00%				
Wood		100.00%				
12) How many new bridges were built or are under construction during 1988-90 and what are their lengths?						
Total:	7	16	0	0	2	1
Less 30 ft.						
Cast in Place						
Pre Cast Concrete						
Steel						
Wood		3				
30-60 ft.						
Cast in Place		1				
Pre Cast Concrete	2	1			1	1
Steel		10				
Wood						
60-120 ft.						
Cast in Place					1	
Pre Cast Concrete	3	1				
Steel	1					
Wood						

11) What percentage of new bridges are typically built by the following sources?						
Contractor:						
Cast in Place			50.00%		0.00%	100.00%
Pre Cast Concrete	100.00%		100.00%		25.00%	100.00%
Steel					75.00%	
Wood						
County Crews						
Cast in Place			50.00%	100.00%		
Pre Cast Concrete		95.00%		100.00%		
Steel				100.00%		
Wood				100.00%		100.00%
12) How many new bridges were built or are under construction during 1988-90 and what are their lengths?						
Total:	2	1	0		0	1
Less 30 ft.						
Cast in Place						
Pre Cast Concrete						
Steel						
Wood						
30-60 ft.						
Cast in Place				2		
Pre Cast Concrete	1	1				
Steel						
Wood						
60-120 ft.						
Cast in Place						1
Pre Cast Concrete	1					
Steel						
Wood						

13) What was the average cost						
$ Per FT of Deck for the following years?						
1988						
Cast in Place						
Pre Cast Concrete	$54.00		$50.00			
Steel					$141.00	
Wood						
1989						
Cast in Place						
Pre Cast Concrete	$59.00		$50.00			
Steel						
Wood						
1990						
Cast in Place						
Pre Cast Concrete	$124.00		$50.00			
Steel						
Wood						
14) Indicate the number of suppliers of the						
following bridge materials and the						
proximity to the county?						
< 10 miles:						
Cast in Place	2			3		
Pre Cast Concrete					0	
Steel					0	
Wood					0	
10-100 miles:						
Cast in Place	3	3				
Pre Cast Concrete	1		1		0	
Steel					0	
Wood					0	
100-200 miles:						
Cast in Place		3			5	
Pre Cast Concrete	1	2	2	2	2	
Steel				?	?	
Wood				?	?	

		UNK				
13) What was the average cost						
$ Per FT of Deck for the following years?						
1988						
Cast in Place						$185.00
Pre Cast Concrete						
Steel			$5.00			
Wood						
1989						
Cast in Place	$55.00		$154.00	$100.00		$185.00
Pre Cast Concrete						
Steel				$90.00		
Wood						
1990						
Cast in Place				$120.00		
Pre Cast Concrete						
Steel						
Wood						
14) Indicate the number of suppliers of the following bridge materials and the proximity to the county?						
< 10 miles:						2
Cast in Place	1	3				
Pre Cast Concrete		0				
Steel		0				
Wood		0	1			
10-100 miles:				3		5
Cast in Place		0				2
Pre Cast Concrete	1	2	2			2
Steel		0				1
Wood		0	4			
100-200 miles:						
Cast in Place				2		3
Pre Cast Concrete						3
Steel			>4	1		2
Wood						

13) What was the average cost						
$ Per FT of Deck for the following years?						
1988						
Cast in Place				$60.70	$56.00	$56.92
Pre Cast Concrete						
Steel						
Wood						
1989						
Cast in Place	$90.00				$43.00	$56.13
Pre Cast Concrete	$90.00					
Steel	$140.00					
Wood						
1990						
Cast in Place						$54.62
Pre Cast Concrete						
Steel						
Wood						
14) Indicate the number of suppliers of the						
following bridge materials and the						
proximity to the county?						
< 10 miles:						
Cast in Place					1	
Pre Cast Concrete					1	
Steel						
Wood						
10-100 miles:						
Cast in Place					3	4
Pre Cast Concrete		3			3	1
Steel						2
Wood					3	
100-200 miles:						
Cast in Place						
Pre Cast Concrete				1		3
Steel						
Wood						2

13) What was the average cost						
$ Per FT of Deck for the following years?						
1988						
Cast in Place						
Pre Cast Concrete	$80.00		$51.00			$90.00
Steel						
Wood						
1989						
Cast in Place						
Pre Cast Concrete	$100.00					$80.00
Steel						
Wood						
1990						
Cast in Place						
Pre Cast Concrete	$90.00					$100.00
Steel						
Wood						
14) Indicate the number of suppliers of the following bridge materials and the proximity to the county?						
< 10 miles:						
Cast in Place	1	1		1	2	2
Pre Cast Concrete		0				
Steel		0				
Wood		2		2		
10-100 miles:						
Cast in Place	3	10		2		6
Pre Cast Concrete		3		3	1	1
Steel		2		3	3	
Wood		10		3	1	1
100-200 miles:						
Cast in Place						
Pre Cast Concrete						4
Steel						
Wood						4

13) What was the average cost						
$ Per FT of Deck for the following years?						
1988						
Cast in Place						$75.00
Pre Cast Concrete	$52.00					$65.00
Steel						$70.00
Wood		$25.00				$50.00
1989						
Cast in Place						$80.00
Pre Cast Concrete						$70.00
Steel						$70.00
Wood		$25.00		$96.00		$50.00
1990						
Cast in Place						$85.00
Pre Cast Concrete						$70.00
Steel						$75.00
Wood		$30.00		$71.00		$45.00
14) Indicate the number of suppliers of the following bridge materials and the proximity to the county?						
< 10 miles:						
Cast in Place	2			1		2
Pre Cast Concrete						0
Steel						2
Wood						3
10-100 miles:						
Cast in Place	4			3		3
Pre Cast Concrete	3	1		2		1
Steel		3		5		3
Wood		1		2		6
100-200 miles:						
Cast in Place						6
Pre Cast Concrete	1	1				3
Steel						6
Wood		3				10

13) What was the average cost						
$ Per FT of Deck for the following years?						
1988						
Cast in Place				$0.00		
Pre Cast Concrete				$70.00		
Steel				$0.00		
Wood				$0.00		
1989						
Cast in Place				$30.00		
Pre Cast Concrete				$30.00		$170.00
Steel				$0.00		
Wood				$0.00		
1990						
Cast in Place						
Pre Cast Concrete	$110.00					
Steel						
Wood						
14) Indicate the number of suppliers of the following bridge materials and the proximity to the county?						
< 10 miles:						
Cast in Place				0		2
Pre Cast Concrete				0		
Steel				0		
Wood				0		
10-100 miles:						
Cast in Place				2	X	
Pre Cast Concrete				1	X	2
Steel				0	X	
Wood				1	X	
100-200 miles:						
Cast in Place				3		
Pre Cast Concrete		1		1		
Steel				0		
Wood				1		

13) What was the average cost						
$ Per FT of Deck for the following years?						
1988						
Cast in Place		$65.00				
Pre Cast Concrete	$95.00	$90.00			$29.00	
Steel		$60.00				
Wood		$40.00				
1989						
Cast in Place		$0.00			$73.00	
Pre Cast Concrete	$106.00	$100.00				
Steel	$76.00	$70.00				
Wood		$50.00				
1990						
Cast in Place	$140.00	$0.00				
Pre Cast Concrete		$118.00				
Steel		$70.00				
Wood		$50.00				
14) Indicate the number of suppliers of the following bridge materials and the proximity to the county?						
< 10 miles:						
Cast in Place			1	1		
Pre Cast Concrete			1			
Steel			1			
Wood			1			
10-100 miles:						
Cast in Place						
Pre Cast Concrete						1
Steel						
Wood						
100-200 miles:						
Cast in Place					5	
Pre Cast Concrete		2		3	4	
Steel		2		10		
Wood		1		3		

13) What was the average cost						
$ Per FT of Deck for the following years?						
1988						
Cast in Place				$70.00		
Pre Cast Concrete						
Steel						
Wood						
1989						
Cast in Place						
Pre Cast Concrete						
Steel						
Wood						
1990						
Cast in Place						
Pre Cast Concrete	$80.50					
Steel						
Wood						
14) Indicate the number of suppliers of the following bridge materials and the proximity to the county?						
< 10 miles:						
Cast in Place						
Pre Cast Concrete						
Steel					0	
Wood						
10-100 miles:						
Cast in Place				3		
Pre Cast Concrete		2				1
Steel					0	
Wood						2
100-200 miles:						
Cast in Place	4					
Pre Cast Concrete						
Steel					0	
Wood						

15) Weight use following Materials:						
Substructure:						
Cast in Place	10	10	10	80	10	7
Pre Cast Concrete	1	1	4	20	0	7
Steel	1	1	1		5	1
Wood	1	1	1		5	1
Superstucture:						
Cast in Place	1	2	1	10	1	8
Pre Cast Concrete	10	10	10	90	8	6
Steel	1	1	1		2	1
Wood	1	1	1		6	1
Decking:						
Cast in Place	1	5	8	20	1	7
Pre Cast Concrete	10	5	8	80	8	5
Steel	1	1	1		0	1
Wood	1	1	1		6	1
16) Rate Cast in Place:						
Simple Design	5	3	1	2	3	4
Familiarity in Department	5	5	5	2	4	4
Material Cost	5	3	1	3	3	3
Material Availability	5	4	5	4	5	5
Construction Cost	4	2	2	4	3	3
Contractor's Familiarity	5	5	5	3	4	4
Speed of Construction		2	2	2	1	3
Low Maintenance	4	4	4	3	3	4
Durability	4	5	4	3	3	4
Funding Available	3	4	3	3	3	4
Aesthetics	3	3	4	3	3	3
Other						

15) Weight use following Materials:						
Substructure:						
Cast in Place	10	10	60	10		5
Pre Cast Concrete		1	40	3		0
Steel		5		9		5
Wood		1		5		0
Superstucture:						
Cast in Place			40	9		
Pre Cast Concrete	10		10	10		10
Steel				1		
Wood			50	1		
Decking:						
Cast in Place			25	10		
Pre Cast Concrete	10		25	9		10
Steel			-	1		
Wood			50	1		
16) Rate Cast in Place:						
Simple Design	5	3	3	5	3	
Familiarity in Department	4	4	1	5	3	
Material Cost	4	3	2	5	4	
Material Availability	4	4	3	5	4	
Construction Cost	4	3	2	3	3	
Contractor's Familiarity	4	3	3	4	5	
Speed of Construction	4	2	3	1	1	
Low Maintenance	4	5	4	5	4	
Durability	4	5	5	5	4	
Funding Available	4	3	3	3	4	
Aesthetics	3	3	4	5	3	
Other						

15) Weight use following Materials:						
Substructure:						
Cast in Place	9	8		10	10	10
Pre Cast Concrete				1	1	1
Steel	1				5	1
Wood	1				1	1
Superstucture:						
Cast in Place	9			6	10	3
Pre Cast Concrete		10		4	10	10
Steel	8					4
Wood	1					1
Decking:						
Cast in Place	9			9	10	1
Pre Cast Concrete				2	10	1
Steel	8					10
Wood	1				3	1
16) Rate Cast in Place:						
Simple Design	2	3	4	4	5	5
Familiarity in Department	3	3	4	3	4	5
Material Cost	3	3	3	3	5	5
Material Availability	5	4	4	3	5	5
Construction Cost	1	2	2	4	4	5
Contractor's Familiarity	5	4	3	3	3	5
Speed of Construction	1	2	2	2	4	5
Low Maintenance	5	4	4	4	5	5
Durability	4	4	4	4	5	5
Funding Available		3	3	4	4	5
Aesthetics	3	3	3	3	3	3
Other						

15) Weight use following Materials:						
Substructure:						
Cast in Place	10	10	10		8	
Pre Cast Concrete	5	5	0		5	
Steel	5	1	0		1	
Wood	1	1	2	10	1	
Superstucture:						
Cast in Place	10	10	10		5	
Pre Cast Concrete	5	10	10		10	
Steel	5	7	2		1	
Wood	1	3	2	10	1	
Decking:						
Cast in Place	10	10	10		10	
Pre Cast Concrete	10	10	5		5	
Steel	1		0		1	
Wood	1		3	10	1	
16) Rate Cast in Place:						
Simple Design	5	4	3	5	4	4
Familiarity in Department	5	5	3	1	3	4
Material Cost	5	3	3	3	3	3
Material Availability	5	5	3	5	4	4
Construction Cost	3	3	3	3	2	2
Contractor's Familiarity	5	4	3	2	4	3
Speed of Construction	5	3	3	2	1	2
Low Maintenance	5	5	5	5	3	4
Durability	5	5	5	5	3	5
Funding Available	5	4	3	5	3	3
Aesthetics	3	3	3	2	5	3
Other						

15) Weight use following Materials:						
Substructure:						
Cast in Place	10	9		1	10	9
Pre Cast Concrete	1	1		10		2
Steel	1	5		10	1	9
Wood	1	3		1		6
Superstucture:						
Cast in Place	10	1		7		8
Pre Cast Concrete	10	9		10	10	9
Steel	1	1		8		6
Wood	1	3		9		5
Decking:						
Cast in Place	10	1		9		8
Pre Cast Concrete	6	9		10		9
Steel	1	1				5
Wood	1	3		8		6
16) Rate Cast in Place:						
Simple Design	3	1	2	2	3	2
Familiarity in Department	3	1	4	3	3	4
Material Cost	5	1	2	3	3	2
Material Availability	5	3	5	5	3	5
Construction Cost	5	1	2	3	3	3
Contractor's Familiarity	5	2	3	5	3	3
Speed of Construction	2	1	2	3	3	2
Low Maintenance	5	5	4	4	3	3
Durability	5	5	4	4	3	2
Funding Available	3	5	3	1	3	3
Aesthetics	5	5	3	5	3	4
Other						

15) Weight use following Materials:						
Substructure:						
Cast in Place	10	10		10		
Pre Cast Concrete		10		0		
Steel		8		0		8
Wood		8		0		
Superstucture:						
Cast in Place		10				
Pre Cast Concrete	10	10		9		10
Steel		8				
Wood		8				
Decking:						
Cast in Place		10		9		
Pre Cast Concrete	10	10		9		10
Steel		8				
Wood		8				
16) Rate Cast in Place:						
Simple Design	3	5	1	5	4	1
Familiarity in Department	3	3	1	5	4	1
Material Cost	1	3	3	4	3	1
Material Availability	1	5	4	4	5	3
Construction Cost	2	3	3	4	2	1
Contractor's Familiarity	4	5	3	5	5	1
Speed of Construction	2	5	2	2	3	1
Low Maintenance	4	5	4	3	4	3
Durability	4	5	4	3	4	3
Funding Available	5	4	3	3	4	3
Aesthetics	3	4	3	3	3	3
Other						

15) Weight use following Materials:						
Substructure:						
Cast in Place	4	10			9	1
Pre Cast Concrete	1	7			10	10
Steel	5	6			1	1
Wood	0	5			1	1
Superstucture:						
Cast in Place	0	6			9	1
Pre Cast Concrete	3	7			10	10
Steel	2	10			1	1
Wood	0	5			1	1
Decking:						
Cast in Place	1	6			9	1
Pre Cast Concrete	7	7			10	10
Steel	0	10			1	1
Wood	2	5			1	1
16) Rate Cast in Place:						
Simple Design	1	5	4	5	3	3
Familiarity in Department	2	3	2	5	3	3
Material Cost	3	3	3	5	4	3
Material Availability	3	5	3	3	4	3
Construction Cost	2	3	2	4	3	3
Contractor's Familiarity	3	5	3	5	4	3
Speed of Construction	2	2	4	1	4	3
Low Maintenance	5	5	5	5	4	3
Durability	5	5	5	5	4	3
Funding Available	4	3	3	3	5	3
Aesthetics	3	3	3	4	4	3
Other				3		

15) Weight use following Materials:						
Substructure:						
Cast in Place	4	10		9		10
Pre Cast Concrete				3		0
Steel				9		0
Wood				3		2
Superstucture:						
Cast in Place		7		7		1
Pre Cast Concrete				3		10
Steel				3		1
Wood				7		2
Decking:						
Cast in Place		10		7		4
Pre Cast Concrete	10			3		8
Steel				8		0
Wood				4		8
16) Rate Cast in Place:						
Simple Design	3		5	4		
Familiarity in Department	3	5	3	4		
Material Cost	4	5	4	4		
Material Availability	4	5	4	4		
Construction Cost	3		4	5		
Contractor's Familiarity	3		4	3		
Speed of Construction	2	1	3	2		
Low Maintenance	3	5	3	2		
Durability	3	5	4	3		
Funding Available	2		3	1		
Aesthetics	3		3	2		
Other			3			

17) Rate Pre-Cast/Prefabricated Concrete						
Simple Design	5	4	3	5	4	3
Familiarity in Department	5	5	5	4	4	2
Material Cost	4	3	5	4	3	3
Material Availability	5	3	5	3	4	3
Construction Cost	4	4	4	3	3	4
Contractor's Familiarity	4	4	5	4	4	3
Speed of Construction	5	5	5	5	5	4
Low Maintenance	4	5	4	3	3	4
Durability	4	4	4	3	3	4
Funding Available	3	4	3	3	3	4
Aesthetics	3	3	4	3	2	3
Other						
18) Rate Steel						
Simple Design	2	3	2	2	1	3
Familiarity in Department	2	2	1	2	1	2
Material Cost	2	3	2	3	3	2
Material Availability	2	3	4	2	2	3
Construction Cost	2	3	2	3	3	2
Contractor's Familiarity	2	3	3	3	3	3
Speed of Construction	2	4	2	3	3	2
Low Maintenance	2	4	1	2	1	1
Durability	3	5	2	3	1	4
Funding Available	2	5	4	3	3	3
Aesthetics	2	4	4	3	3	3
Other						

17) Rate Pre-Cast/Prefabricated Concrete						
Simple Design		4	3	5	5	5
Familiarity in Department		4	1	5	4	5
Material Cost		3	4	5	4	3
Material Availability		4	4	4	3	3
Construction Cost		3	4	4	3	4
Contractor's Familiarity		3	3	4	5	4
Speed of Construction		4	4	4	5	4
Low Maintenance		5	4	4	5	4
Durability		5	5	4	5	4
Funding Available		3	3	3	5	5
Aesthetics		3	4	4	5	3
Other						
18) Rate Steel						
Simple Design		3	3	5	1	
Familiarity in Department		3	3	3	1	
Material Cost		3	3	3	1	
Material Availability		3	3	3	1	
Construction Cost		3	1	2	1	
Contractor's Familiarity		3	2	3	1	
Speed of Construction		4	1	4	1	
Low Maintenance		3	1	2	1	
Durability		4	4	3	1	
Funding Available		3	2	3	1	
Aesthetics		3	3	3	1	
Other					1	

17) Rate Pre-Cast/Prefabricated Concrete						
Simple Design	5	4	4	3	5	5
Familiarity in Department	5	3	3	3	5	5
Material Cost	3	2	4	3	5	5
Material Availability	1	4	4	3	5	5
Construction Cost	1	4	4	3	4	5
Contractor's Familiarity	3	4	3	4	4	5
Speed of Construction	4	5	5	5	5	5
Low Maintenance		5	5	4	5	5
Durability	2	4	5	4	4	5
Funding Available		4	4	4	5	5
Aesthetics	2	4	4	3	4	5
Other						
18) Rate Steel		None in County				
Simple Design	5		2	3	3	4
Familiarity in Department	3		2	2	1	2
Material Cost	2		2	3	3	3
Material Availability	4		2	3	3	4
Construction Cost	2		2	2	3	4
Contractor's Familiarity	3		3	2	1	3
Speed of Construction	2		2	3	3	5
Low Maintenance	2		2	2	1	5
Durability	5		3	3	1	5
Funding Available			3	2	3	5
Aesthetics	5		3	3	3	4
Other						

17) Rate Pre-Cast/Prefabricated Concrete						
Simple Design	5	5	3	2	2	4
Familiarity in Department	3	5	4	1	3	4
Material Cost	5	3	3	1	3	3
Material Availability	4	4	3	1	2	4
Construction Cost	5	3	3	1	3	3
Contractor's Familiarity	5	3	4	1	2	4
Speed of Construction	5	5	5	4	5	3
Low Maintenance	5	5	5	4	2	4
Durability	5	4	5	4	3	5
Funding Available	5	3	3	4	3	4
Aesthetics	5	3	3	3	2	3
Other				1		

18) Rate Steel						
Simple Design	1	2	2	2	2	2
Familiarity in Department	1	2	2	1	1	3
Material Cost	1	2	2	2	2	2
Material Availability	1	3	2	3	3	2
Construction Cost	1	3	2	2	2	2
Contractor's Familiarity	1	3	2	1	2	3
Speed of Construction	1	3	4	3	4	4
Low Maintenance	1	2	2	2	1	2
Durability	1	3	3	4	2	3
Funding Available	1	3	3	4	3	4
Aesthetics	1	3	3	2	4	3
Other				1		

17) Rate Pre-Cast/Prefabricated Concrete						
Simple Design	3	4	5	2	4	5
Familiarity in Department	3	4	4	3	3	4
Material Cost	3	3	5	5	3	5
Material Availability	2	4	5	5	3	4
Construction Cost	3	3	5	5	3	4
Contractor's Familiarity	4	4	5	5	3	5
Speed of Construction	5	4	5	5	4	5
Low Maintenance	5	4	5	5	3	4
Durability	5	4	5	5	3	4
Funding Available	3	4	5	1	3	3
Aesthetics	4	4	5	5	3	2
Other			5			

18) Rate Steel						
Simple Design	3	4	4	4	2	3
Familiarity in Department	2	1	5	3	2	5
Material Cost	4	1	3	3	2	3
Material Availability	3	4	3	5	4	3
Construction Cost	3	2	3	4	3	2
Contractor's Familiarity	2	3	4	5	3	2
Speed of Construction	4	4	5	5	3	2
Low Maintenance	1	3	4	5	1	1
Durability	1	3	5	5	3	4
Funding Available	3	4	3	1	3	3
Aesthetics	3	3	3	3	3	3
Other						

17) Rate Pre-Cast/Prefabricated Concrete						
Simple Design	4	5	3	5	5	5
Familiarity in Department	3	5	1	5	3	5
Material Cost	4	3	3	3	4	5
Material Availability	4	3	1	4	5	5
Construction Cost	3	5	3	3	4	5
Contractor's Familiarity	4	5	1	5	3	5
Speed of Construction	4	5	4	5	5	5
Low Maintenance	4	5	4	5	3	3
Durability	4	5	4	5	3	3
Funding Available	4	5	3	5	3	3
Aesthetics	4	3	3	5	3	3
Other		5				
18) Rate Steel						
Simple Design	3	3	3	4	5	1
Familiarity in Department	3	4	2	2	5	1
Material Cost	4	3	3	3	3	3
Material Availability	4	3	1	2	3	3
Construction Cost	3	3	3	3	3	3
Contractor's Familiarity	4	4	1	4	5	3
Speed of Construction	4	3	3	4	5	3
Low Maintenance	3	3	2	4	1	1
Durability	3	3	2	4	2	3
Funding Available	4	5	3	4	3	3
Aesthetics	3	3	3	4	3	3
Other						

17) Rate Pre-Cast/Prefabricated Concrete						
Simple Design	5	5	3	3	5	4
Familiarity in Department	4	3	2	5	5	5
Material Cost	3	4	3	5	5	4
Material Availability	4	4	3	3	5	4
Construction Cost	2	2	3	4	5	3
Contractor's Familiarity	4	5	4	5	3	4
Speed of Construction	5	2	4	5	5	5
Low Maintenance	5	5	5	5	5	5
Durability	5	5	5	5	5	5
Funding Available	4	5	3	3	3	4
Aesthetics	3	4	3	4	4	5
Other				3		2
18) Rate Steel						
Simple Design	3	5	1	5	3	3
Familiarity in Department	3	5	1	5	3	3
Material Cost	3	3	3	1	3	3
Material Availability	3	5	3	3	3	3
Construction Cost	3	3	3	5	3	3
Contractor's Familiarity	3	3	3	3	3	3
Speed of Construction	4	5	2	4	2	3
Low Maintenance	2	5	2	2	2	3
Durability	3	5	3	3	2	3
Funding Available	4	3	3	3	3	3
Aesthetics	3	4	2	2	4	3
Other				3		

17) Rate Pre-Cast/Prefabricated Concrete						
Simple Design	3	5	4	3	5	
Familiarity in Department	3	5	3	2	5	5
Material Cost	2	3	2	4	5	
Material Availability	5	5	2	3	5	
Construction Cost	4		3	3	5	
Contractor's Familiarity	4		3	3	5	
Speed of Construction	5	5	4	4	5	4
Low Maintenance	5	5	4	3	5	5
Durability	5	5	4	3	5	
Funding Available	2		4	1	3	
Aesthetics	3		4	2	5	
Other						

18) Rate Steel						
Simple Design				4	5	
Familiarity in Department				4	5	
Material Cost				4	3	
Material Availability				4	4	
Construction Cost				4	3	
Contractor's Familiarity				4	3	
Speed of Construction				4	3	
Low Maintenance				4	4	
Durability				4	4	
Funding Available				1	3	
Aesthetics				2	4	
Other						

19) Rate Engineered Wood						
Simple Design	4	3	3	2	5	4
Familiarity in Department	4	2	1	2	5	3
Material Cost	4	4	2	3	3	4
Material Availability	2	3	5	2	3	3
Construction Cost	4	4	2	3	3	3
Contractor's Familiarity	3	2	4	2	4	3
Speed of Construction	4	4	2	3	5	4
Low Maintenance	2	3	1	1	3	2
Durability	2	4	1	1	2	2
Funding Available	1	5	4	3	3	2
Aesthetics	4	5	5	3	4	3
Other						
20) Weight Factors:						
Superstructure:						
Familiarty of Design	10	5	10	5	9	5
Material Costs	9	10	5	4	9	7
Material Availability	10	9	6	6	7	8
Construction Costs	9	10	10	6	9	8
Speed of Construction	10	8	10	7	9	5
Maintenance Costs	7	9	10	9	8	7
Durability	9	8	10	8	8	7
Total Life Cycle Costs	8	9	10	10	5	7
Required by Funding Source	8	10	5	5	1	7
Aesthetics	1	9	1	3	5	5
Environmental Impact	5	8	5	2	5	5
Substructure:						
Familiarty of Design	10	7	10	5	9	5
Material Costs	9	10	10	4	6	7
Material Availability	10	9	10	6	5	8
Construction Costs	9	10	8	6	7	8
Speed of Construction	10	8	10	7	7	5
Maintenance Costs	9	10	10	8	7	7
Durability	9	10	10	9	7	7
Total Life Cycle Costs	10	10	10	10	5	7
Required by Funding Source	8	10	5	5	1	7
Aesthetics	1	5	5	3	1	5
Environmental Impact	5	8	5	2	5	5

19) Rate Engineered Wood						
Simple Design		3	3	5		
Familiarity in Department		3	1	5		
Material Cost		2	5	5		
Material Availability		3	5	5		
Construction Cost		3	4	4		
Contractor's Familiarity		2	3	4		
Speed of Construction		4	4	5		
Low Maintenance		2	2	2		
Durability		2	2	2		
Funding Available		3	3	3		
Aesthetics		3	4	3		
Other						
20) Weight Factors:						
Superstructure:						
Familiarty of Design		5	2	10		8
Material Costs		10	8	5		8
Material Availability		10	6	8		8
Construction Costs		10	10	10		5
Speed of Construction		5	3	8		6
Maintenance Costs		10	7	10		8
Durability		10	4	10		8
Total Life Cycle Costs		10	9	10		5
Required by Funding Source		5	1	10		3
Aesthetics		5	3	5		3
Environmental Impact		6	5	5		8
Substructure:						
Familiarty of Design		5	2	10		
Material Costs		9	8	5		
Material Availability		10	6	8		
Construction Costs		10	10	10		
Speed of Construction		5	3	8		
Maintenance Costs		10	7	10		
Durability		10	4	10		
Total Life Cycle Costs		10	9	10		
Required by Funding Source		5	1	10		
Aesthetics		1	3	5		
Environmental Impact		6	5	5		

19) Rate Engineered Wood						
Simple Design	4	5	4	3	5	5
Familiarity in Department	2	4	4	3	4	2
Material Cost	3	4	5	4	3	3
Material Availability	2	4	5	4	3	3
Construction Cost	3	4	5	4	3	3
Contractor's Familiarity	3	3	3	3	1	2
Speed of Construction	3	4	5	3	2	1
Low Maintenance	4	1	2	2	1	2
Durability	1	2	1	2	1	3
Funding Available		2	1	2	2	5
Aesthetics	5	2	1	3	1	5
Other						
20) Weight Factors:						
Superstructure:						
Familiarty of Design	10		5	1	5	8
Material Costs	10		7	8	5	10
Material Availability	10		5	5	10	10
Construction Costs	10		7	9	5	10
Speed of Construction	8		5	3	9	8
Maintenance Costs	8		9	7	10	10
Durability	8		10	5	10	10
Total Life Cycle Costs	10		10	2	10	5
Required by Funding Source			10	10	5	5
Aesthetics	10		5	4	5	5
Environmental Impact			5	6	1	7
Substructure:						
Familiarty of Design	8		5	1	5	8
Material Costs	10		7	8	9	10
Material Availability	10		5	5	5	10
Construction Costs	10		7	9	9	10
Speed of Construction	10		5	3	9	8
Maintenance Costs	10		9	7	10	10
Durability	10		10	5	10	10
Total Life Cycle Costs	8		10	2	9	5
Required by Funding Source			10	10	5	5
Aesthetics	8		5	4	5	5
Environmental Impact			5	6	1	7

19) Rate Engineered Wood						
Simple Design	1	4	4	4	5	2
Familiarity in Department	1	5	3	1	3	2
Material Cost	4	5	3	4	4	3
Material Availability	3	5	4	4	4	3
Construction Cost	5	3	4	4	4	3
Contractor's Familiarity	2	3	3	4	3	3
Speed of Construction	2	3	4	4	4	4
Low Maintenance	2	1	2	4	2	2
Durability	2	1	3	4	2	2
Funding Available	2	3	3	4	3	3
Aesthetics	4	3	3	4	4	4
Other				3		
20) Weight Factors:						
Superstructure:						
Familiarty of Design	5	10	8	7	8	6
Material Costs	5	8	10	9	9	7
Material Availability	5	8	10	9	8	7
Construction Costs	5	8	10	9	8	10
Speed of Construction	5	6	8	10	6	5
Maintenance Costs	10	8	10	10	10	10
Durability	10	8	10	10	10	10
Total Life Cycle Costs	10	6	10	9	10	5
Required by Funding Source	10	10	5	5	5	8
Aesthetics	5	5	7	10	8	5
Environmental Impact	5	6	10	10	5	8
Substructure:						
Familiarty of Design	5	10	8	8	6	6
Material Costs	5	8	10	9	10	7
Material Availability	5	8	10	9	9	7
Construction Costs	5	8	10	9	8	10
Speed of Construction	5	6	8	10	6	5
Maintenance Costs	10	8	10	10	10	10
Durability	10	8	10	10	10	10
Total Life Cycle Costs	10	6	10	9	10	5
Required by Funding Source	10	10	5	6	5	8
Aesthetics	2	5	7	10	8	5
Environmental Impact	10	6	10	10	5	8

19) Rate Engineered Wood						
Simple Design	3	4	1	5	3	3
Familiarity in Department	3	3	4	5	3	4
Material Cost	5	3	1	5	3	4
Material Availability	4	3	2	4	4	5
Construction Cost	4	3	1	5	4	4
Contractor's Familiarity	3	4	4	3	3	4
Speed of Construction	4	5	3	5	2	4
Low Maintenance	1	4	1	3	1	2
Durability	1	4	1	3	1	2
Funding Available	3	4	1	5	3	3
Aesthetics	3	4	2	5	2	4
Other						
20) Weight Factors:						
Superstructure:						
Familiarty of Design	1	5	9	5	*	8
Material Costs	5	10	10	10	7	6
Material Availability	5	6	9	8	6	7
Construction Costs	8	9	9	10	7	8
Speed of Construction	5	7	8	8	4	9
Maintenance Costs	10	8	10	10	10	9
Durability	10	4	10	10	9	10
Total Life Cycle Costs	10	3	10	5	10	8
Required by Funding Source	10	6	10	5	9	6
Aesthetics	6	2	7	5	3	7
Environmental Impact	8	1	6	5	3	7
Substructure:						
Familiarty of Design	1	5	8	5	*	8
Material Costs	5	10	10	10	7	8
Material Availability	5	6	8	8	6	7
Construction Costs	8	9	8	10	7	8
Speed of Construction	5	7	2	8	4	9
Maintenance Costs	10	8	10	10	10	7
Durability	10	4	8	10	9	9
Total Life Cycle Costs	10	3	10	5	10	9
Required by Funding Source	10	6	10	5	9	7
Aesthetics	6	2	5	5	3	7
Environmental Impact	8	1	6	5	3	8

19) Rate Engineered Wood						
Simple Design	3	3	3	4	5	3
Familiarity in Department	3	4	3	2	1	1
Material Cost	4	4	3	2	3	3
Material Availability	5	5	4	4	3	3
Construction Cost	3	3	3	4	4	3
Contractor's Familiarity	2	3	4	3	3	1
Speed of Construction	4	3	4	4	5	3
Low Maintenance	2	3	3	2	2	3
Durability	2	3	2	2	3	3
Funding Available	1	5	3	3	2	3
Aesthetics	3	3	3	4	4	3
Other						
20) Weight Factors:						
Superstructure:						
Familiarty of Design	1	5	5	8		5
Material Costs	7	5	3	10	5	5
Material Availability	7	5	2	9	9	5
Construction Costs	7	5	3	9	4	5
Speed of Construction	10	8	5	7	10	5
Maintenance Costs	2	8	10	10	6	5
Durability	4	8	10	10	7	5
Total Life Cycle Costs	10	8	10	10	1	5
Required by Funding Source	8	6	10	7	2	3
Aesthetics	1	5	3	4	8	3
Environmental Impact	1	5	5	8	3	3
Substructure:						
Familiarty of Design	1	5	5	9		5
Material Costs	7	5	3	10	5	5
Material Availability	7	5	2	9	9	5
Construction Costs	7	5	3	5	4	5
Speed of Construction	6	8	5	6	10	5
Maintenance Costs	2	8	10	10	6	5
Durability	4	8	10	10	7	5
Total Life Cycle Costs	10	8	10	10	1	5
Required by Funding Source	8	6	10	5	2	3
Aesthetics	1	5	3	4	8	3
Environmental Impact	1	5	8	8	3	3

19) Rate Engineered Wood						
Simple Design	1	5	3	5	3	3
Familiarity in Department	2	5	1	5	3	3
Material Cost	3	3	3	5	3	3
Material Availability	2	5	3	2	3	3
Construction Cost	2	3	2	5	3	3
Contractor's Familiarity	2	3	3	3	3	3
Speed of Construction	2	3	3	5	2	3
Low Maintenance	1	1	1	5	2	3
Durability	1	3	1	2	2	3
Funding Available	3	3	3	3	3	3
Aesthetics			5	5	4	3
Other				3		
20) Weight Factors:						
Superstructure:						
Familiarty of Design		5	3	5	6	8
Material Costs		8	6	8	4	7
Material Availability		8	5	8	5	3
Construction Costs		10	10	8	7	7
Speed of Construction		10	2	5	8	6
Maintenance Costs		10	9	10	9	8
Durability		10	7	8	3	7
Total Life Cycle Costs		10	8	10	10	9
Required by Funding Source		5		5	2	1
Aesthetics		5	1	6	1	1
Environmental Impact		10	4	2		1
Substructure:						
Familiarty of Design		5	2	5		6
Material Costs		8	5	9		1
Material Availability		8	4	8		4
Construction Costs		10	10	9		7
Speed of Construction		10	3	5		3
Maintenance Costs		10	9	10		1
Durability		10	8	9		6
Total Life Cycle Costs		10	7	10		4
Required by Funding Source		5		5		1
Aesthetics		5	1	7		1
Environmental Impact		10	6	3		1

19) Rate Engineered Wood						
Simple Design				2	5	
Familiarity in Department				3	1	
Material Cost				2	1	
Material Availability				4	1	
Construction Cost				4	5	
Contractor's Familiarity				3	1	
Speed of Construction				4	5	
Low Maintenance				2	1	
Durability				3	1	
Funding Available				1	3	
Aesthetics				5	5	
Other						
20) Weight Factors:						
Superstructure:						
Familiarty of Design	5	10	6	7	10	
Material Costs	9		6	9	10	
Material Availability	10	10	6	5	10	
Construction Costs	9		6	10	10	
Speed of Construction	9	8	8	8	10	
Maintenance Costs	7		5	7	10	
Durability	8	10	5	7	10	
Total Life Cycle Costs	7	10	5	8	10	
Required by Funding Source	10		6	1	0	
Aesthetics	3		6	4	1	
Environmental Impact			6	9	10	
Substructure:						
Familiarty of Design	5	10	6	7	10	
Material Costs	9		6	9	10	
Material Availability	10	10	6	5	10	
Construction Costs	9		6	10	10	
Speed of Construction	9	10	8	8	10	
Maintenance Costs	7		5	7	10	
Durability	8	10	5	7	10	
Total Life Cycle Costs	7	10	5	8	10	
Required by Funding Source	10		6	1	0	
Aesthetics	3		6	4	1	
Environmental Impact			6	9	10	

Appendix C SPSS Data Definition File and Data File

```
clude "bridges1.def".
TA LIST FILE="BRIDGES1.DAT"
OUNTY 1-2   STAFF 4   STAFFNUM 6-7   MONEYRPR 9-12  MONEYRPL 14-17
NDSCOU 19-21   FUNDSSTA 23-25    FUNDSFED 27-29   CODES 31   NUMBRIDG 33-35
TLT400 37-39   ADTBTWN 41-43   ADTGT200 45-47   REPLCONC 49-50
PLSTEE 52-53   REPLWOOD 55-56   REPL30 58-59    REPL60 61-62   REPL120 64-65
WCIP 67-68   NEWPRE 70-71    NEWSTEEL 73-74   NEWWOOD 76-77
UBCIP 1-2   SUBPRE 3-4    SUBSTEEL 5-6   SUBWOOD 7-8
PERCIP 9-10   SUPERPRE 11-12    SUPERSTE 13-14    SUPERWOO 15-16
CKCIP 17-18   DECKPRE 19-20   DECKSTEE 21-22   DECKWOOD 23-24
PDESIG 26  CIPFAMIL 27  CIPMATCO 28  CIPMATAV 29 CIPCONST 30
PCONTR 31   CIPSPEED 32   CIPMAINT 33   CIPDURAB 34   CIPFUNDI 35
PAESTH 36
REDESIG 1   PREFAMIL 2   PREMATCO 3   PREMATAV 4   PRECONST 5
ECONTR 6   PRESPEED 7   PREMAINT 8   PREDURAB 9   PREFUNDI 10
EAESTH 11
EDESIG 13   STEFAMIL 14   STEMATCO 15   STEMATAV 16   STECONST 17
ECONTR 18   STESPEED 19   STEMAINT 20   STEDURAB 21   STEFUNDI 22
EAESTH 23
OODESIG  1   WOOFAMIL  2   WOOMATCO  3   WOOMATAV  4   WOOCONST  5
OCONTR  6   WOOSPEED  7   WOOMAINT  8   WOODURAB  9   WOOFUNDI 10
OAESTH 11
PDESIG 13-14   SUPMATCO 15-16   SUPMATAV 17-18  SUPCONST 19-20
PSPEED 21-22   SUPMAINT 23-24   SUPDURAB 25-26  SUPLIFEC 27-28
PFUNDI 29-30   SUPAESTH 31-32   SUPENVIR 33-34
BDESIG 36-37   SUBMATCO 38-39   SUBMATAV 40-41  SUBCONST 42-43
BSPEED 44-45   SUBMAINT 46-47   SUBDURAB 48-49  SUBLIFEC 50-51
BFUNDI 52-53   SUBAESTH 54-55   SUBENVIR 56-57
UMMY 1-19.

RIABLE LABELS
TAFF "DOES COUNTY HAVE A FULL TIME STAFF"
TAFFNUM "NUMBER OF ENGINEERS ON THE STAFF"
ONEYRPR "HOW MUCH IS SPENT ANNUALLY ON BRIDGE REPAIR IN K $ "
ONEYRPL "HOW MUCH IS SPENT ANNUALLY ON BRIDGE REPLACEMENT IN K $"
UNDSCOU "SOURCES OF FUNDING % COUNTY"
UNDSSTA "SOURCES OF FUNDING % STATE"
UNDSFED "SOURCES OF FUNDING % FEDERAL"
ODES "WHAT CODES ARE USED TO DESIGN NEW BRIDGES?"
UMBRIDG "HOW MANY BRIDGES ARE UNDER COUNTY JURISDICTION"
DTLT400 "# BRIDGES WITH AVERAGE DAILY TRAFFIC LESS THAN 400"
DTBTWN "#BRIDGES WITH AVERAGE DAILY TRAFFIC BETWEEN 400 AND 2000"
DTGT200 "#BRIDGES WITH AVERAGE DAILY TRAFFIC GREATER THAN 2000"
EPLCONC "# CONCRETE BRIDGES THAT REQUIRE REPLACEMENT"
EPLSTEE "# STEEL BRIDGES THAT REQUIRE REPLACEMENT"
EPLWOOD "# WOOD BRIDGES THAT REQUIRE REPLACEMENT"
EPL30 "# BRIDGES LESS THAN 30 FEET REQUIRING REPLACEMENT"
EPL60 "# BRIDGES BTWN 30 AND 60 FT THAT REQUIRE REPLACEMT"
EPL120 "# BRIDGES > 60 FT < 120 FT THAT REQUIRE REPLACEMENT"
EWCIP "# NEW CAST IN PLACE CONCRETE BRIDGES"
EWPRE "# NEW PRECAST CONCRETE BRIDGES"
EWSTEEL "# NEW STEEL BRIDGES"
EWWOOD "# NEW WOOD BRIDGES"
UBCIP TO SUBWOOD "WEIGHT THE USE IN THE SUBSTRUCTURE"
UPERCIP TO SUPERWOO "WEIGHT THE USE IN THE SUPERSTRUTURE"
ECKCIP TO DECKWOOD "WEIGHT THE USE IN THE DECKING"
IPDESIG TO CIPAESTH "RATE CAST IN PLACE BRIDGES FOR THE CHARACTERISTIC OF"
REDESIG TO PREAESTH "RATE PRE CAST CONCRETE BRIDGES FOR THE CHARACTERISTIC OF"
TEDESIG TO STEAESTH "RATE STEEL BRIDGES FOR THE CHARACTERISTIC OF"
OODESIG TO WOOAESTH "RATE ENGINEERED WOOD BRIDGES FOR THE CHARACTERISTIC OF"
UPDESIG TO SUPENVIR "WEIGHT THE RELATIVE IMPORTANCE FOR SUPERSTRUCTURES"
UBDESIG TO SUBENVIR "WEIGHT THE RELATIVE IMPORTANCE FOR SUBSTRUCTURES".
```

```
SSING VALUE
TAFF(9)        STAFFNUM TO FUNDSFED (99)        CODES (9)
MBRIDG TO DECKWOOD (99)        CIPDESIG TO WOOAESTH (9)
PDESIG TO SUBENVIR (99).

LUE LABELS
TAFF 1 "NO" 2 "YES"
ODES 1 "AASHTO" 2 "STATE" 3 "AASHTO and STATE" 4 "COUNTY" 5 "FHWA"
UBCIP TO DECKWOOD 1 "LOW UTILIZATION" 10 "HIGH UTILIZATION "
IPDESIG TO WOOAESTH 1 "DISADVANTAGE" 3 'NEUTRAL' 5 "ADVANTAGE"
UPDESIG TO SUBENVIR 1 "LEAST IMPORTANT"  10 "MOST IMPORTANT".
```

```
ROR        1, Text: AA
VALID COMMAND--Check spelling.  If it is intended as a continuation of a
evious line, the terminator must not be specified on the previous line.
 a DATA LIST is in error, in-line data can also cause this error.
is command not executed.
```

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This procedure was completed at 15:00:07
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55454454433 22222222322
44424342214 1009100910070908080105 1009100910090910080105

02 1 00 0014 0100 020 000 080 2 015 013 001 001 01 03 00 01 03 99 00 02 00 02
1001010102100101050501 01 35342524543
45334455443 32333344554
32434243455 0510091008090809100908 0710091008101010100508

03 1 01 0035 0200 020 000 080 1 056 030 020 006 01 01 06 04 03 01 00 08 00 00
1004010101100101080801 01 15152524434
35554554434 21242321244
31252421145 1005061010101010050105 1010100810101010050505

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54433453333 22323332333
22323231133 0504060607090810050302 0504060607080910050302

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55333453234 0909070909080805010505 0906050707070705010105

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0707010108060101070501 01 44353434443
32334344443 32232321433
43433342223 0507080805070707070505 0507080805070707070505

07 1 00 0020 0100 020 000 080 1 065 065 000 000 01 00 12 00 13 00 00 13 00 00
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99999999999 99999999999
99999999999 9999999999999999999999 9999999999999999999999

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44343345533 33333343433
33233242233 0510101005101010050506 0509101005101010050106

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31444344534 33331211423
31554342234 0208061003070409010305 0208061003070409010305

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55554452233 1005081008101010100505 1005081008101010100505

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55454454433 22222222322
44424342214 1009100910070908080105 1009100910090910080105

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Appendix D List of Respondents

Appendix D List of Respondents

SPSS Number	County	Name	Address	City State Zip
1	Adams County, WA	Walt Olsen	210 W. Broadway	Ritzville, WA. 99169
2	Asotin County, WA	Richard Weaver, Pl	P.O. Box 160	Asotin, WA. 99402
3	Benton County, WA	Dennis Skeate, PE	P.O. Box 110	Prosser, WA. 99350
4	Chelan County, WA	Lloyd Berry, PE/L:	Courthouse, Wenatc	Wenatchee, WA. 98801
5	Clallam County, WA	Don McInnes	223 E. 4th	Port Angeles, WA. 98362
6	Columbia County, WA	Gary Gasaway, PE	341 E. Main St.	Dayton, WA. 99328
7	Cowlitz County, WA	Kenneth C. Stone	207 N. 4th	Kelso, WA. 98626
8	Ferry County, WA	Greg Pezoldt, Eng	P.O. Box 344	Republic, WA. 99166
9	Grays Harbor, WA	Russ Esses	P. O. Box 511	Montesano, WA 98563
10	Island County, WA	Roy Allen, PE	Box 5000	Coupeville, WA 98239
11	Jefferson County, WA	Bruce Laurie	P.O. Box 1220	Port Townsend, WA 98368
12	King County, WA	Doug Mattoon, PE	500 4th Avenue	Seattle, WA 98104
13	Kitsap County, WA	David E. Dickson, .	614 Division	Port Orchard, WA 98366
14	Kittitas County, WA	John Nixon	205 W.5th, Room 1	Ellensburg, WA 98926
15	Klickitat County, WA	Ed Hoyle, PE	205 So. Columbus	Goldendale, WA 98620
16	Lewis County, WA	Darrel Q. McMurph	P.O. Box 899	Chehalis, WA. 98532
17	Lincoln County, WA	Glen Oliver, PE	Box 368	Davenport, WA 99122
18	Pacific County, WA	John Bay	Box 66	South Bend, WA 98586
19	Pend Oreille County, W	Michael Rabe, PE	P.O. Box 5000	Newport, WA 99156
20	Pierce County, WA	Don Peterson, P.E.	2401 So. 35th	Tacoma, WA 98409-7487
21	San Juan County, WA	David O' Kane	Box 729	Friday Harbor, WA 98250
22	Skagit County, WA	Chet Reid	Rm 203 Co. Admin.	Mt. Vernon, WA 98273
23	Snohomish County, WA	Darrell Ash, PE	2918 Colby Street	Everett, WA 98201
24	Thurston County, WA	Dale Rancour	2000 Lakeridge Dr.	Olympia, WA 98502
25	Whitman County, WA	Lon R. Pedersen	P.O. Box 430	Colfax, WA 99111
26	Baker County, OR	William S. McHane	3050 E Street	Baker City, OR 97814
27	Benton County, OR	Roger Irvin, Assist	360 S.W. Avery Av	Corvallis, OR 97333
28	Clatsop County, OR	Randy Trevillian	1100 Olney Ave.	Astoria, OR 97103
29	Douglas County, OR	Morrie Chappel	219 County Courthc	Roseburg, OR 97470
30	Gilliam County, OR	John Russum	P.O. Box 427	Condon, OR 97823
31	Grant County, OR	Doug Kruse	P.O. Box 190	Canyon City, OR 97820
32	Hood River County, OR	James F. Lyon, Di	918 18th Street	Hood River, OR 97031
33	Malheur County, OR	Ray Stooks, Bridg	251 'B' St. West, B	Vale, OR 97918-1357
34	Multnomah County, OR	Stan M. Ghezzi, P.E	1629 S.E. 190th	Portland, OR 97233
35	Polk County, OWayne L.	Rickert Jr., Director	206 County Courthc	Dallas, OR 97338
36	Tillamook County, OR	Jon Oshel, Directo	503 Marolf Loop	Tilamook, OR 97141
37	Umatilla County, OR	Ivan E. Pointer	3920 Westgate	Pendleton, OR 97801
38	Union County, OR	Richard Comstock	P.O. Box 1103	La Grande, OR 97850
39	Wallowa County, OR	Merlin 'Skip' Lovel	P.O. Box 219	Enterprise, OR 97828
40	Wasco County, OR	Daryl Ingebo, Bridc	County Courthouse,	The Dalles, OR 97058
41	Yamhill County, OR	Dan Linscheid	2060 Lafayette Ave	McMinnville, OR 97128
42	Lewis County, ID	Director of County	Lewis County Cour	Nezperce, ID 83543
43		Jim Stackhouse	Box 1418	Bonner's Ferry, ID 83805

Appendix D List of Respondents

SPSS Number	County	Name	Address	City State Zip
44	Fremont County, ID	Lyle I. Thompson	215 Farnsworth Wa	Rigby, ID 83442
45	Shoshone County, ID	Shoshone County	Drawer A	Shoshone, ID 83352
46	Nez Perce County, ID	R.N. Flowers Count	805 26th St North	Lewiston, ID 83501
47	Canyon County, ID			
48	Mason County, ID	Elden L. Reed	P.O. Box 357	Shelton, WA 98584
49	Clark County, WA	Brian Vincent, PE	P.O. Box 5000	Vancouver, WA. 98668
50	Boise County, ID	Director of Public	P. O. Box 156	Idaho City, ID 83631

Appendix E Summary of Costs for New Bridges

County	CIP 88	PRE 88	STE 88	WOO 88	CIP 89	PRE 89	STE 89	WOO 89	CIP 90	PRE 90	STE 90	WOO 90
Adams, WA		$54.00				$59.00				$124.00		
Asotin, WA												
Benton, WA		$50.00				$50.00				$50.00		
Chelan, WA												
Clallam, WA		$0.00	$141.00									
Clark, WA												
Columbia, WA					$55.00	$0.00						
Cowlitz, WA												
Ferry, WA		$0.00		$5.00		$154.00						
Greys Harbor, WA						$100.00		$90.00		$120.00		
Island, WA												
Jefferson, WA		$185.00				$185.00						
King, WA					$90.00	$90.00	$140.00					
Kitsap, WA												
Kittitas, WA												
Klickitat, WA		$60.70										
Lewis, WA		$56.00				$43.00						
Lincoln, WA		$56.92				$56.13				$54.62		
Pacific, WA		$80.00				$100.00				$90.00		
Pend Oreille, WA												
Pierce, WA		$51.00										
San Juan, WA												
Skagit, WA												
Snohomish, WA		$90.00				$80.00				$100.00		
Thurston, WA		$52.00										
Whitman, WA		$0.00		$25.00		$0.00		$25.00		$0.00		$30.00
Baker, OR												
Benton, OR						$0.00		$96.00		$0.00		$71.00
Clatsop, OR												
Douglas, OR	$75.00	$65.00	$70.00	$50.00	$80.00	$70.00	$70.00	$50.00	$85.00	$70.00	$75.00	$45.00
Gilliam, OR										$110.00		
Grant, OR												

CIP (Cast-in-place), PRE (Precast), STE (Steel), WOO (Wood)

County	CIP 88	PRE 88	STE 88	WOO 88	CIP 89	PRE 89	STE 89	WOO 89	CIP 90	PRE 90	STE 90	WOO 90
Hood River, OR												
Malheur ,OR		$70.00			$30.00	$30.00						
Multnomah, OR												
Polk, OR						$170.00						
Tillamook, OR		$95.00				$106.00	$76.00		$140.00	$0.00		
Umatilla, OR	$65.00	$90.00	$60.00	$40.00		$100.00	$70.00	$50.00		$118.00	$70.00	$50.00
Union OR												
Wallowa, OR												
Wasco, OR		$29.00			$73.00	$0.00						
Yamhill, OR												
Boundary, ID										$80.50		
Canyon, ID												
Fremont ,ID												
Lewis, ID												
Nez Perce, ID												
Shoshone, ID	$70.00	$0.00										
Boise, ID	$70.00											
Averages	1988	1989	1990									
Cast-in-Place	$70.00	$65.60	$112.50									
Precast	$72.31	$92.88	$91.71									
Steel	$90.33	$89.00	$72.50									
Wood	$30.00	$62.20	$196.00									

CIP (Cast-in-place), PRE (Precast), STE (Steel), WOO (Wood)

458-770

Thesis
B8143 Brown
c.1 Assessment of short
span bridge materials.